CODAC: Coastal Operation Data Acquisition Catamaran

Naval Architecture Research Group

Ocean Engineering Design 2007

Team Everglide

Stephanie Groleau, Team Leader

Joshua Revord

Tyler Robbins

Bob Vandedrinck

Final Report
July 2007

Letter of Transmittal

Florida Institute of Technology
Department of Marine and Environmental Systems
Marine Field Projects

TO: Dr. Stephen Wood
            Department of Marine and Environmental Systems
            150 W. University Blvd.
            Melbourne, FL 32901

FROM: CODAC Naval Architecture Group
            150 W. University Blvd.
            Melbourne, FL 32901

RE: Final Design Report

Dr. Wood,

Attached please find the final design report of the CODAC naval architecture project submitted for your review as requested. This report includes all information and data known to date, from the conceptual design to all completed testing and data collected. It has been completed as fully as possible with all of the information known currently.

We would like to thank the Department of Marine and Environmental Systems and the College of Engineering for their funds, Ed Robbins of Robbins Mobile Welding for the donated material, labor, and time, as well as the consultants Dr. Sainsbury, Dr. Wood, and Bill Battin for their valuable time.

Sincerely,

Stephanie Groleau   _____

Joshua Revord   _____

Tyler Robbins   _____

Bob Vandedrinck   _____

Executive Summary

The CODAC project purpose is to analyze and test the effects of hull spacing and tunnel sections on the behavior of planing and semi-displacement catamarans. Eventually, we aim to create an equation that relates hull spacing along with bridge spacing to a grounding effect lift/cushioning that can be applied to improve sea keeping in full scale vessels. With the use of the LOMAC and Displacement catamaran hulls currently owned by DMES and the design and production of a tunnel section. The testing will include measurements of average accelerations (indicating the smoothness of the ride), velocity, turning radius, and the behavior of the hull in open rough water. The project will be a combination and continuation of the previous LOMAC and displacement catamaran projects. After completing the required repairs and changes to the hull and data is acquired, our final goal of this project is to experimentally derive an equation relating the bridge (tunnel section) dampening with the hull spacing. This type of research and equation has, to our knowledge, never been achieved.

Table of Contents

Acknowledgements

This project would not have been achievable without the assistants of contributors. We would like to express gratitude toward the College of Engineering for the additional $500 given to all ocean engineering senior design projects. Also we are very thankful for previous donations from Structural Composites Inc. of West Melbourne, which also includes Eric Roehl, Director of Testing Services, and Ron Reichard, CEO. Structural Composites provided the use of its CNC mill, fiberglass cloth and matte donations. Furthermore, we would like to thank Ed Robbins, owner of Robbins Mobile Welding. Our welding labor and materials are donated along with a 0.25 inch thick 5051 aluminum 1'x 3' sheet, a 1' x 3' piece of 5051 0.125 inch aluminum, a 12' of square anodized section of tubing, and a 6' section of anodized cylindrical tubing. We thank Plastic Design for their last minute help with the Sintra purchase for our tunnel section. Thanks are also due to Eduardo Gonzales for his constant advice. We are grateful, as always, to Bill Battin for his help with painting and all the little things we forgot. Finally, we would like to thank Dr. Wood for giving us guidance and encouragement throughout the project.

List of Figures

List of Acronyms

1. CNC: Computer Numerically Controlled
2. LOMAC: Littoral Operated Multipurpose Auxiliary Craft
3. CODAC: Coastal Operation Data Acquisition Catamaran
4. MFP: Marine Field Project
5. DMES: Department of Marine and Environmental Systems
6. FIT: Florida Institute of Technology

1.0 Introduction

1.1 Purpose

Marine Field Projects (MFP) in the department of Ocean Engineering serve several purposes. Students learn how to work in teams, develop a unique design, use current software, become machine shop certified, build the project, and finally, analyze the results in a professional report. The purpose of this report is to describe the 2007 MFP project that researched and tested hull spacing on a semi-displacement hull catamaran. As a continuation of last year's naval architecture project and their, this year's group, Team Everglide, aimed to build upon the existing equipment and use it to investigate different features and characteristics of displacement-type catamaran vessels. The team will upgrade the systems to better correlate to a full scale vessel and try to find relationships between hull spacing and sea-keeping using accelerometers.

Catamaran vessels are recognized to be very stable due to the large spacing between hulls yet very fuel efficient. Displacement-type catamarans do not have the same low accelerations like planing hulls when they lift out of the water, have the quality of added stability due to their round hull shape. In this year's project the team will further investigated this matter of sea-kindliness and stability by constructing an enclosed tunnel section to join the two hulls which though the means of grounding effects could contribute to the dampening of wave accelerations. Additionally the team also designed a system to systematically increase hull spacing in order to investigate at which point the hulls have their optimum performance. Both of these systems are interchangeable between model catamarans of similar dimensions therefore enabling it to be used in comparative studies.

1.2 Report Overview

This report will start out by explaining the theory behind the semi-displacement hull and the theory behind the CODAC designs. Then the conceptual designs will be illustrated, and how they changed into the final designs. All materials purchased will by described and the reasons for choosing them. After, the report goes through the manufacturing stages step by step with all changes and mistakes pointed out. Then, the report describes the testing goals and plan of action, followed by the testing results. Finally, the team concludes the report with recommendations for the future what the project accomplished.

2.0 Theory/Background

Before creating the project proposal, Team Everglide contacted the 2006 Naval Architecture MFP group and Eduardo Gonzalez to come up with design ideas. After creating a list of possible research areas, the team investigated the theories behind our proposed designs. The research showed that in normal conditions a marine craft will perform only as good as its ability to reduce viscous drag. In reducing this drag there are three main components that a Naval Architect looks at to improve the move ability of his vessel. Viscous drag, fundamental fluid design, the grounding effect, and wave making greatly affect the performance and reduce fuel consumption. Due to the lack of comprehensive research, the team has taken part in a study that will try to understand the dynamics involved in a common catamaran system in which hull spacing and tunnel section dampening will be analyzed to maximize performance of a duel hull system.

2.1 Viscous Drag

Viscous drag is the first important factor in efficiency. Viscous drag is proportional to the surface area that inhibits any median difference. In other words, when any fluid comes into contact with any other fluid or solid that is of a difference density, the flow of the fluid resists its movement because of inter molecular bonds. Bonds such as Metallic, Van der Wals, Ionic, and Hydrogen bonds are just a few that are common and these bonds represent the structure of the substance. Metallic bonds are often very strong bonds and because of this the density of metals tends to be high because of the atomic forces are very strong and keep the atomic structure packed tightly. In navel design, water is the median in which the most resistance is apparent as a sea going vessel is operating. In water, which is very viscous, hydrogen bonds are the most controlling force in a vessel's performance. In analyzing the dynamics of a boat it can be seen that overcoming the viscous effects of the water is inevitable; only by taking and improving the smoothness of the hull and the geometry can the interaction between the water and surface of the hull be improved. By taking away the roughness of the hull and creating a theoretically smooth surface in the design phase, the fluid flow past the boundary layer will be kept at a minimum.

2.2 Fundamental Design

Fundamental design of a marine vessel is also a necessity to the performance of the vessel. The design of the vessel will be determined on its required operating speed and functionality. In order to understand, three types of marine vessels have been categorized to represent their functionality.

The first type of vessel that is apparent is the displacement type. This type of vehicle is most affiliated with large freighters and barges that carry large amounts of cargo. These types of ships are often heavy and their shear size makes them very hard to move. Displacement hulls often inhibit great stability for many reasons. One reason would be that the design shape of the vessel is to promote maximum storage and results in a more rectangular geometry. This geometry allows for the vessel to maximize storage while minimizing its ability to operate fluidly. An example of a displacement hull cross-section can be seen in figure 2.2.1. It can be seen that because of its wetted surface area significant power supply would be needed to displace the water that it will be subject to during operation.
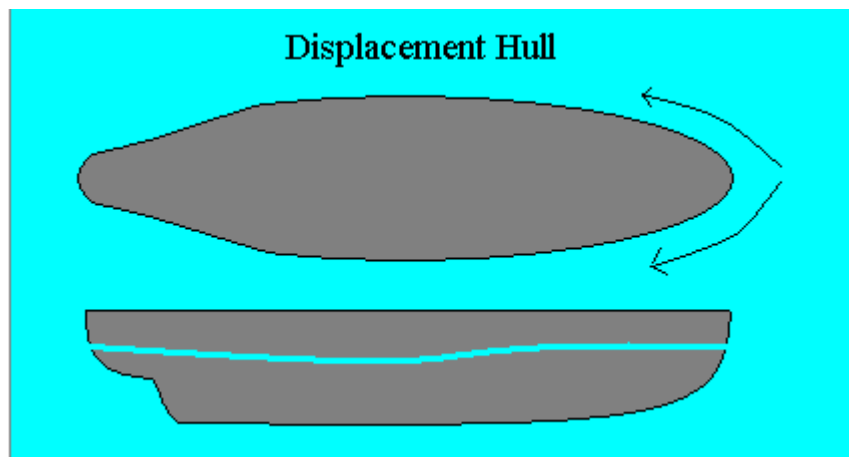
Figure 2.2.1: Displacement Hull

The next design type of marine vehicle is a planing hull, like the LOMAC by Guardino and Gonzalez.

Figure 2.2.2: The Guardino/Gonzalez LOMAC

A planing hull is a hull that utilizes hydrostatic forces to reduce surface friction by using pressure differences to thrust the boat out of the water. This type of hull can be seen in various types of recreational crafts that allow for a minimization of fuel costs with the reduction of weight handling capacity. This type of hull is usually very light weight and inhibits an un-linear velocity profile that is the result of a drag reduction due to an instantaneous velocity jump. This jump is due to the pressure difference that becomes apparent at the boundary layer of the boat due to the increase in speed. This increase applies a force to the hull and with the geometry propels that boat out of the water and reduces the wetted surface area. A picture of a planing hull can be seen below in figure 2.2.3.
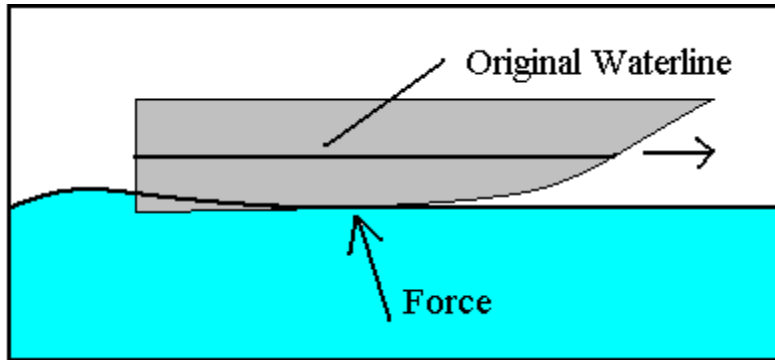
Figure 2.2.3: Planing hull

Finally, the last type of hull is the semi displacement hull. This hull is a mixture between the displacement and the planning hull and has the unique ability to change depending on its operational speed. In relatively slow speeds it acts much like a displacing hull but as it increased in speed it becomes a planning hull. This ability makes it a middle ground boat and allows the boat to have medium haling capacity as well as speed. This semi-displacement design in a catamaran can create a grounding effect. The CODAC hulls are modeled after the semi displacement Glacier Bay.

Figure 2.2.4: 2006 MFP semi displacement hull

2.3 Grounding Effect

The grounding effect is one area of interest for our project. This concept can be seen in nature when birds fly close to the water to harness the pressure fluctuations that become apparent at the interface. This pressure difference is the result of the instantaneous compression of the air column just above the waters surface. As a foil is placed over the water the air molecules disperse and because of the relatively limited exit regions produce an additional force that helps keep the object in flight. This concept is important to our project because it will allow the team to determine whether this phenomenon affects the nature of the catamaran in operating conditions. By allowing the tunnel section to be attached and detached the team can analyze the vertical acceleration differences and can determine whether or not there is any significant change in mobility of the vessel.

Figure 2.3.1: (FLYBOAT, 2007)

In figure 2.3.1, a flying boat is designed specifically to harness the grounding effect. Here the vessel compresses the air between itself and the water's surface. Without a ground surface to create a higher pressure from air compression the flying boat could not fly. Therefore this craft is limited to a low elevation flying altitude unlike plains.

Figure 2.3.2: An example of the grounding effect in a catamaran (MARINE PERFORMANCE/RACE ENGINES, 2007)

The offshore racing catamaran seen in figure 2.3.2 experiences the grounding effect. Here the air between the pontoons is slightly compressed. With a high pressure is create it will flow to areas of lower pressure. The only available flow direction for the higher pressure air is up, thus lifting boat or decelerating its descent.

2.4 Wave Making/Hull Spacing Theory

In addition to designing a tunnel for the grounding effect, the team designed a hull spacing structure to cancel waves created by the hulls. Constructive and destructive wave interference is another area of interest that contributes to the ability of a vessel to perform optimally. In being a semi-displacement vessel the vehicle will produce two sets of waves that will result in power loss as the boat is in motion. These wave systems will propagate and in a catamaran system will result in either constructive or destructive interference. In displacing the hulls and changing the spacing of the vehicle the wave trains can be manipulated into canceling out and reducing drag as power is conserved and not wasted to wave making. In changing the hull spacing the vehicle can be optimized in order to harness all of the power that is put in into moving the vessel and not displacing water.

2.5 Similitude

Similitude is the process or art of accurately comparing models to full size vessels using the Froude and Reynolds numbers. When comparing the model and the actual Glacier Bay 2665 the team found that in order for the model to be accurately similar its current operating speed should be increased to 17 kts (20mph) in order for the investigations with the grounding effect to be significant. The calculations based on Froude similitude pertaining to this value can be seen below:

Model Length = 5.5 ft = 1.67 m

Boat Length = 26 ft = 7.92 m

Boat Max Speed = 43 mph = 37 kts = 19.22 m/s

$$Fr = \frac{V_m}{\sqrt{gL_m}} = \frac{V_a}{\sqrt{gL_a}}$$

$$V_m = \frac{V_a\sqrt{gL_m}}{\sqrt{gL_a}}$$

$$V_m = \frac{19.22\sqrt{9.81 \cdot 1.67}}{\sqrt{9.81 \cdot 7.92}} = 8.84\,\frac{m}{s} = 17.18\,kts = 19.77\,mph$$

Where:

V = Velocity

g = gravitational acceleration

L = Length of hull

3.0 Design/Conceptual Phase

This project had a good foundation in the existing displacement hull designed and produced by Clay Danielson et. al. in 2006, but it required a large amount of brainstorming and design work. The structure joining the two hulls and the tunnel section had to be designed from scratch; the new propulsion and electronics systems to reach the required higher speeds also had to be considered, and the hull itself had to be reconditioned as a whole. In order to do this more efficiently the group split into two teams, one working on the structure and tunnel section (Revord and Robbins), and the other on the electronics, propulsion and hull systems (Groleau and Vandedrinck).

3.1 Spacing Structure Design

The design of the spacing structure went though many ideas and phases. Initially flat sliding designs or single-use design were considered, but after careful thought, an intricate system of cams and lock pins was decided upon. The individual parts were first designed in Rhino 3D and then assembled into a single assembly. As the design reached completion, some changes were made to the design of the individual cams and locking mechanisms as well as the mounting systems to the decks. Rhino's .iges format made it very simple for the computer models to be transferred to other software packages such as PTC ProEngineer or MasterCam for manufacturing purposes. The system is designed so that every reposition of the lock pins proved the hulls with a 2" increase in spacing.
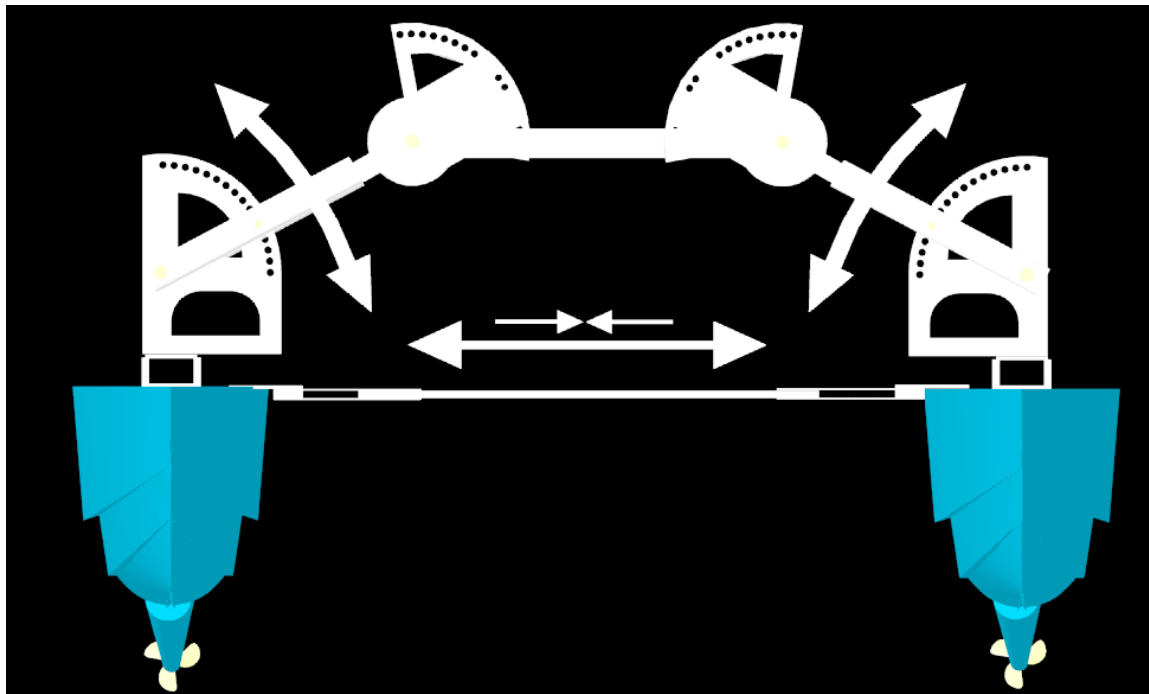
Figure 3.1.1: The final product of the design allowed for the easy expansion and compression of the hulls and created a dynamic system.

3.2 Tunnel Section Design

Similar to the Spacing structure, the tunnel section had to also be designed from scratch and again went though many designs before settling on a single system. It was finally decided that the best system for our purposes was one of sliding plates. Double plates on either side will be attached to the hulls and a middle plate will slide within them. As this section has minimal structural significance and that the forces on it will be very small much attention did not have to be paid to its strength. At a point in its spacing, the middle plate will need to be replaced by a wider one in order to accommodate the larger spacing positions. This design was once again done in Rhino 3D and exported in .iges format.
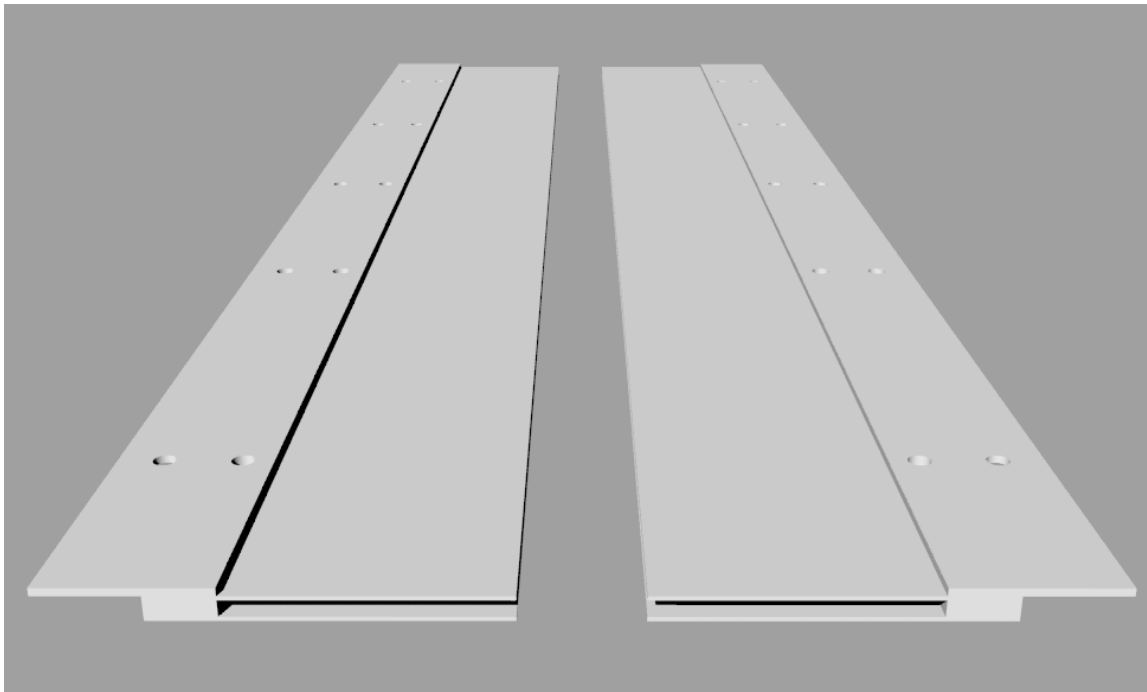
Figure 3.2.1: 3D model of the tunnel sections

3.3 Propulsion System Design

While the tunnel and spacing structures were being designed, a propulsion system that would produce the values found in the similitude section had to be installed. With the many options available on the model RC market for ship propulsion, it was decided that an adaptation of readily available motors and electronics was preferable. The two options for the propulsion of the boat were electrical and gas powered. In order to attain the speeds required by the similitude calculations, the original Graupner 700 BB Turbo electric motors would not be sufficient. Since no electric motors on the RC market would be sufficient, nitro-gas engines were chosen. This added the requirement of cooling and fuel systems to the hulls as well as the need for stronger engine mounts to withstand the torques produced by the engines. In order to accommodate this new propulsion system, accessories such as fuel tanks, fuel lines, cooling water lines, exhaust extensions, and other small details had to also be taken into consideration when designing the whole system.

3.4 Hull/Aesthetics Design

The catamaran hulls also had to undergo a design phase, the layout of the new tunnel sections and propulsion systems called for a new deck made of aluminum rather then the stained wood. The paint on the hulls also had to be renewed due to many kinks and nicks in the surface that would make it prone to water penetration. The decks also required a new sealing system to reduce the water intrusion. The whole existing layout of the hulls also had to stripped and started from scratch.

4.0 Materials/Purchasing

In order to put all of the designed parts of this project to work, the team first had to research the options open to the team on the market and consider them carefully in relation to our budget. In many cases a tradeoff had to found between the quality and price of certain items. A more detailed list of suppliers and prices can be found in the Appendix B.

4.1 Spacing Structure/Tunnel Section

The main materials needed for this part of the project consisted of aluminum sheeting and tubing which was obtained a s a donation from Robbins Mobile Welding in Melbourne, FL a well as party purchased from other sources. This aluminum mainly consisted of 6061 aluminum due to its good performance is the marine environment, however it was more cost effective in certain areas to use other types of aluminum due to its availability as donations. Additionally the traveler tracks on which the structure was to be mounted were purchased from Mc Master-Carr. In order to produce the tunnel section enclosure a lighter material Sintra was purchased at Plastic Design and Mfg Inc in Palm Bay, FL. The team also had to purchase the fastening hardware for the structure at the local Ace Hardware.

4.2 Propulsion System

The new propulsion system for the boat was obtained in many separate orders from different companies. Out main supplier was Space Coast Hobbies in Palm Bay, FL who was able to order the specific engines (OS .18MX Marine) and accessories the team needed at discounted prices,

items purchased here include the electronics, engines, fuel systems, engine and servo mounting hardware, and everything down to the cooling system tubes. Additionally some specific items for the RC boating market were not available at this location so the team were able to purchase them online at FunRCboats.com. Items purchased here included the new shafts, coupler as well as the stuffing tubes. Other minor accessories for the intakes and exhausts were purchased at Ace Hardware once the assembly had started.

4.3 Hull/Aesthetics

The paints and primers (International Paints) for the hulls were purchased though Bill Battin at Lewis Marine in Cocoa, FL using the FIT educational discount. Once delivered, the other painting supplies purchased at Harbor Freight (Spray Guns and sandpaper) as well as extra thinner/cleaner from Ace Hardware.

5.0 Manufacturing/Assembly

5.1 Spacing Structure

In order to evaluate hull spacing in regards to the performance of the boat, a dynamic system was composed in order to allow for differential spacing. This apparatus was designed to allow hull spacing to be controlled precisely so that it can be accurately analyzed. With this in mind, the structure was composed of arm members that are secured with rotational cam systems. These cam systems were originally designed in Rhinoceros and were made to use a pin system to allow for easy contraction and compression of the hulls. To do so, the cams would connect the hulls

and a data acquisition box which would create a ridged body and allows the catamaran to be structurally stable. The cam systems themselves were designed originally in Rhinoceros but where then transferred into MasterCam 10.0. From there, the design was preformed on the CNC machine in the machine shop. This process, although time consuming, yielded three cam members the where to be utilized in our design. Each member was duplicated 4 times and assembled in a fashion so that the members could easily rotate around each other.

Figure 5.1.1: CNC milling of structural cams

Figure 5.1.2: Completed set of cams

In the design the cams used a pin system that would allow the cams to be locked into place as they where situated to the rectangular frame member. This pin system was manufactured by making an L bracket and welding a spring loaded pin on the outside of the cam. All of the cam members were connected by welded aluminum tubing and were bolted down using stainless steel ¼ 20 hex head screws.
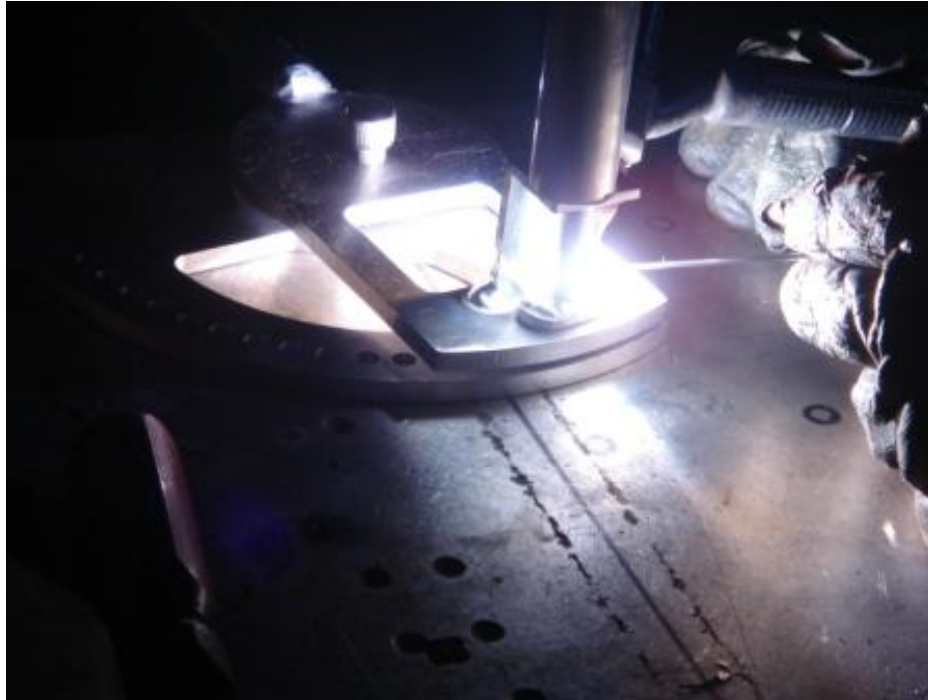
Figure 5.1.3: TIG welding of individual components at Robbins Mobile Welding

The final result was a structure that could displace the hulls in a fashion so that the hulls would both separate and stay parallel to the waters surface. In order to compensate for the center of gravity of the catamaran sliding tracks were also implemented to shift the center of gravity of the boat from bow to stern. This device made it easy to shift the acquisition box or any additional data collection devices into a position so that the boat will perform optimally and have a proper center of gravity.

Figure 5.1.4: Complete spacing structure ready for assembly onto hulls

5.2 Tunnel Section

The tunnel section that was originally formatted was made of .090 inch 6066 aluminum that was cut using a band saw in the machine shop. This design was then secured using stainless steel bolts and was to be fastened to the deck plate in which aluminum sheets could be placed into the leaf system so that the retraction of the hulls could be preformed.

This design was the reconfigured because of weight issues. Because of the density of the metal is so high, the aluminum would not be sufficient so re-modification had to be done in order to reduce weight. A new material was then used was called Sintra. Sintra, which is a foam injected PVC material that is not very dense. This material was cut using a band saw and was fabricated the same way as the aluminum but utilized plastic nuts and bolts to reduce weight. These bolts held together the layers of the leaf system and created a sound body.
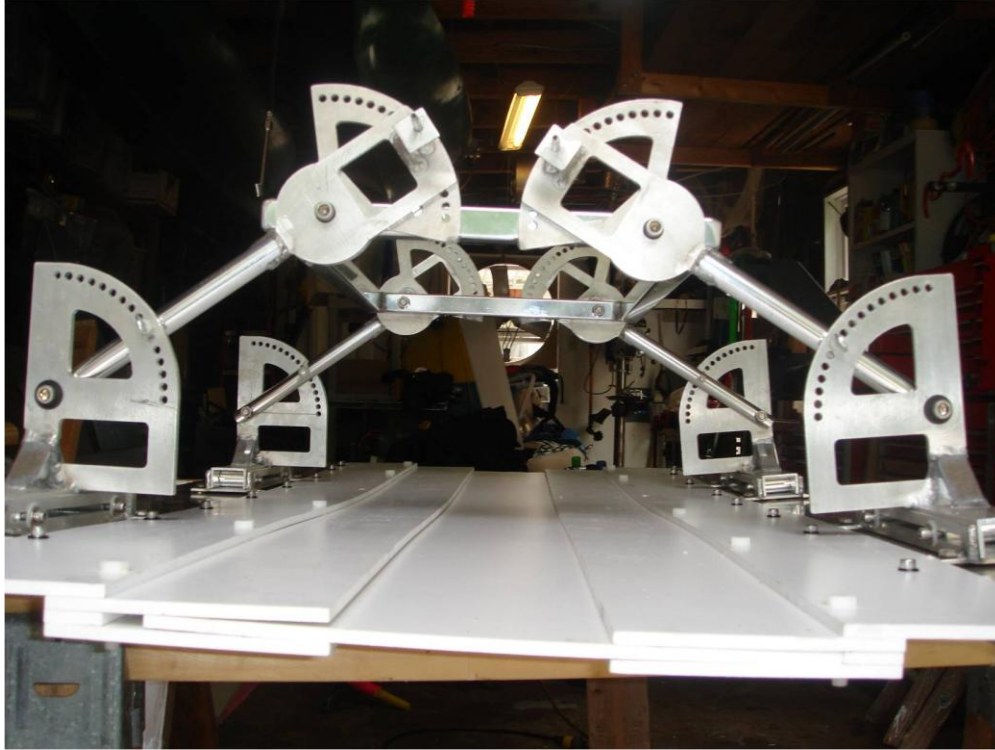
Figure 5.2.1: Side view of tunnel section enclosure system.

5.3 Decks

In order to accommodate for the new design the old wooden decks were removed form the catamaran and an aluminum deck was put into place. This aluminum deck was made out of .090 inch 6066 aluminum that was cut using a circular saw and a skill saw. Aluminum was used in order to allow for the structurally integrity that would be needed to form the foundation of the retractable bridge and tunnel section.

Figure 5.3.1: Cutting of decks

This deck system was originally going to operate as just a foundation but as the design changed the decks had to be modified so that access to the motors could be accomplished. This led to the separation of the decks into two separate sections so that the motors could be accessed easily. The connection of the tunnel section and bridge section also led to the complications in the deck fitting securely to the hulls. This was because the bridge and tunnel sections were secured to the deck with jack nuts which obstructed the hull. Originally the hulls were fitted with a rubber gasket that was cut to fit the hulls but this was not found to be efficient enough and because of the jack nuts a thicker gasket was needed. After purchasing a larger gasket, an end mill was used to cut the half inch material into a correctly fitted rubber gasket. This gasket was then placed on the underside of the deck in order to mark the jack nuts position so that they could be countersunk into the material. In the end, the new gasket was larger then the previous one but offered the deck the ability to be securely fastened to the hulls.

5.4 Hulls

The Existing two displacement hulls created last year by a similar OE design group had been neglected for almost a year and needed refurbishment. First the hulls were stripped of all old electronics and machinery and thoroughly cleaned out. The hulls were then sanded smooth using first 120 and then 200 grit sandpaper to produce a paint ready surface. In order to do this sanding smoothly and effectively a rotary sander was used for the large surfaces and a mouse type sander was used for the smaller chines and curves surfaces.

Figure 5.4.1: Sanding of hulls in preparation of painting

Once sanded and cleaned with a mineral spirit based thinner, the hulls were primed using International Pre-Kote primer for polyurethane paints using a conventional spray gun and

compressed air to produce a smooth thin layer of paint, the paint was thinned using 10% thinner by volume (thinner used was International 216 thinner). This primer was then allowed to dry for 24 hours and was then sanded smooth using 200 grit sandpaper as required by the manufacturer. Once sanded and again cleaned using the mineral spirit based thinner, the hulls were then spray painted using Largo Blue International Polyurethane Topside Enamel Paint. This was done using a gravity fed spray gun to minimize air bubbles.

Figure 5.4.2: Gravity feed spray gun used for enamel coat.

The topside enamel was again thinned using 10% 216 thinner by volume as required by the manufactures instructions. Once painted and dried for 24 hours it was determined that one coat of the paint was sufficient for our use and the hulls were carefully stored ready for assembly. When sanding and painting proper health and safety precautions were taken such as the use of respirators and disposal of all contaminated liquids and solids was done according to university procedures.

5.5 Propulsion

Last years propulsion and electronics were severely damaged due to water intrusion and had to be completely redone. First, the new nitro powered engines had to be fitted into the hulls by means of a new mounting system. Due to the lack of such a mounting system on the market, the team had to design and manufacture our own engine mounts. In order for the engines to work most efficiently, the team had to place the engines the same angle as the shaft tubes by cutting two wood shims at 14 degrees using a miter saw at FIT's Applied Research Lab wood working shop. In order to water proof these mounts, they were coated using a West System slow hardening epoxy which would make them resistant to any water of nitro gas in the bilges. The aluminum engine mounts from Space Coast hobbies were then epoxied and bolted to these shims for extra strength.

Figure 5.5.1: Sealed engine mounts with aluminum base attached (right)

Once dry, the whole mount was then epoxied and screwed into the hull on top of the existing engine mounting plate which prior to the installation had also been removed and re-attached using slow setting epoxy for added strength.

Figure 5.5.2: Original base plate in hull

Figure 5.5.3: Full engine mount installed in hull

This was then left to dry for over 24 hours to allow the epoxy to set to its full working strength. With the mounts in place the engines were bolted into place with the use of bolt and split rings to avoid them loosening due to vibrations. Additional components of the system such as fuel tanks and cooling lines were put it at the end when all other manufacturing had taken place.

Figure 5.5.4: Engine in place on mount with color coded tubing connected

5.6 Drive Shaft

In order to create a functioning system the original drive shafts casings had to be re-modified to allow for proper sealing. In order to due this the original PVC shafts were bored out, and brass tubing was implemented to harness the shafts securely to provide an authentic seal. After installing the shaft casings, the shafts themselves had to be modified.

In the first trial the motors were started and the original flexible shafts obtained an unwanted jump rope action that resulted in lots of noise and vibration of the shafts. This jump rope occurrence was the result of the high RPMs that the motor expelled and was amplified by the mass of the propellers. This was due in part to the coil formation of the flexible shaft system. To combat this, the shafts had to be shortened and brass tubing was used to stabilize the flexible shaft. Once implemented into both systems, the motors were tried again. This time, the brass tubing reduced the vibration of the shaft but compromised the port side shaft by unraveling it and producing an unstructured member.

After analyzing the damage it was seen that the shafts could no longer reach to the mounted motor so a new design had to be established. To do so the team incorporated plastic universal joints which were coupled with a small section of aluminum rod. This rod section was then attached to the motor and then to the u joints. The u joints were then attached the broken shaft so that the motors could be reached.

Figure 5.6.1: Plastic U-Joints

Figure 5.6.2: Plastic U-Joint

The propeller was also changed due to its shear mass. The mass of the propeller was unacceptable and as a result was a main factor in the inability of the shafts to support its inertia. The propellers mass also resulted in random stalling of the engines and rotational torsion of the shafts once started and stopped. The 2006 propellers were replaced with nylon propellers that were secured to the motors by the means of friction as the old shafts were cut and reestablished. These new propellers were less massive and contributed less apparent danger to the shafts. This attachment yielded results but was short-lived due the fracturing of one of the universal joints.

5.7 Electronics

With the engines in place and the rudders attached now the servos for the rudder and throttle control could be installed. As no standard servo supports or cradles are available these had to be custom made in order to firmly hold the servos in place in order to actuate the rudders and

throttle arms. Frames were made using basswood and epoxy based adhesive to ensure strength and durability.
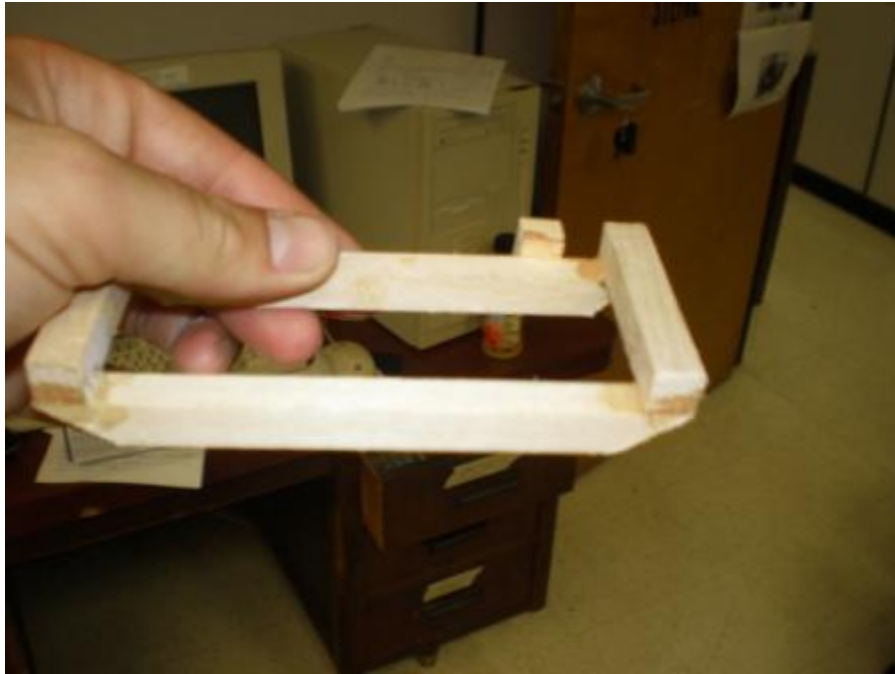
Figure 5.7.1: Complete servo frame ready for installation into hull

Once hardened the whole frame was then placed transversely into the stern of the hulls as seen in the images below, and fastened into place using also epoxy adhesive. The adhesive used was a fast setting G5 adhesive from West Systems. The Hi-Torque JR Sport servos for the rudder control were then mounted into this frame using the rubber shoes and screws, ensuring their alignment with the rudder pushrod. The lower torque servos for the throttle arm control were then attached to the same frame using fastening straps, this is sufficient as the torques and forces on this servo are minimal. Once in place, the servos were then connected to their respective arms using custom sized pushrods and connector pins.

Figure 5.7.2: Complete installation of servo systems

The servo wiring was then routed to the receiver which was mounted in the port hull. These cross hull cables were then run though a waterproofing tube that connected the two hulls to ensure no water intrusion and smooth operation of the servo cables.

5.8 Exhaust System

The original exhaust systems had to be modified in order to expel the exhaust outside of the hulls. Initially the exhaust traveled through a magnesium muffler then into thermoplastic exhaust tubing. Since the thermoplastic tubing was not long enough to expel the exhaust out of the hulls and longer segments of this tubing were not available, the team had to manufacture our own exhaust pipe.

The first attempt to create our own exhaust pipe was by connecting a high pressure hose section to the mufflers. This hose initially worked until the exhaust began to melt the high pressure hose at its connection with the mufflers. Secondly the team attempted to create exhaust pipes from brass tubing. The original brass tubing was heated with a torch in order to bend it so that it aligned with an already predrilled exhaust hole on the hull decks. Then slits were cut at the base of the brass pipes where they would connect to the mufflers. These cuts would allow the pipes to deform under the stresses form hose clamps which would compress the brass onto the muffler nipples. At our first attempt of using hose clamps to connect the brass to the muffler, the mufflers magnesium nipple chipped off.

Figure 5.8.1: Exhaust pipes

So the team needed a new way to connect the brass exhaust pipes to the mufflers. The team used JB Weld for this second connection. JB Weld is an epoxy designed for high temperature environments and primarily used for filling cracks in engine blocks. The JB Weld was applied at the muffler connection and at the bass of the exhaust pipe. The JB Weld attached the exhaust system however cracks formed at the connections with repetitive use. To strengthen the

connection JB Weld was again applied while at the same time with a string lashing. The exhaust pipe and muffler were slowly lashed together at additional weld was applied. The lashing was used to add fibrous structure to the weld for strength. This additional connection held until the motors where properly tuned. Once the motors were tuned an extreme vibration occurred from a higher output of RPMs. This completely destroyed out exhaust connection.

With the exhaust system now undergoing an extreme vibration from the motors the team decided to give-up with the connection of the exhaust pipes to the muffler nipples. To handle the vibration the team needed a sturdier way to join the muffler to an exhaust pipe. Therefore, the team would clamp the exhaust pipe around the entire muffler. To do this copper tubing was clamped around the entire muffler with hose clams then bent upward toward new exhaust vents in the deck
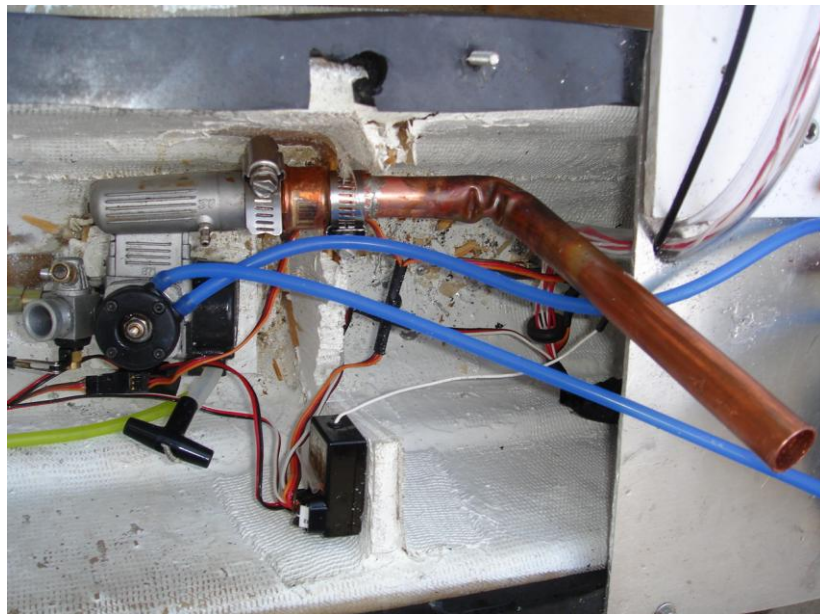
Figure 5.8.2: Exhaust system attached to motors

5.9 Final Assembly

Once all of the individual components of the project were completed, they were all integrated into one. The engines and electronics were completely placed into the hulls, and the decks were fastened using stainless steel fasteners though the rubber seals. In order to find an approximate location for the structure the center of buoyancy was located experimentally by manually forcing the hulls down into water and finding the location at which the force was to be applied to so this equally on both sides. Once in place the spacing structure was then attached to the decks and the exhaust and air intake holes and deflectors put in place. This entire system was then put into a test tank in order to determine the actual water lien of the catamaran and to ensure correct trim of the vessel. With this complete it was determined that the rudder pushrods had to sealed in order to avoid water intrusion, this was done with the use of actuator cable seals from the cycling industry. These rubber seals allow for a certain degree of linear motion even when firmly attached to both sides. With all the components in place, final adjustments and changes were made to optimize the design and aesthetics such as logos and names were also put on.

Figure 5.9.1: CODAC completely assembled with engine hatches open.

Once fully established the vehicle was now ready to obtain power that would be in the form of gas motors. Because of the inability to access the motors properly to ignite the glow plug, the original design for a hatch had to be aborted in order to compensate for the restricted access. This was the result of the sliding track systems position right above the piston head. To compensate for this the tunnel section and the deck system was cut in order to allow the frame system to swivel around the front sliding tracks and produce a hatch system to get to the motors. This allowed for easy access to the motors where wing nuts were place in the stern section of the hatch to improve functioning efficiency.

6.0 Pre-Test Preparations

6.1 Engine Break-In

   In order to run the engines for data acquisition purposes the engines need to be properly ran in, in order to ensure seamless and smooth running. If this break in period is not met, engines might run inconsistently causing errors in our data. According to the manufactures instructions in order to fully break in the engine 5 full tanks of gas must be ran through before regular usage of the engine. The first tank must be run though at low to medium throttle at a rich mixture using heavy fuel to properly lubricate the moving parts; this first tank is to be consumed at the mixture screw set at 2 full turns (720 degrees). Once the first tank is fully consumed, the mixture needle is to be closed 30 degrees and another tank run though; this procedure is repeated for all 4 consecutive tanks (OS owner's instruction manual). Throughout this break in procedure, the team did ensure that the engine was thoroughly cooled by running the boat on water and/or manually pumping cold water though the cylinder head by means of a hand pump. Once run in the engines will start more swiftly and run more consistently, stalling less which enables for more efficient and accurate data collection.

Figure 6.1.1: Final Assembly after the successful pool test

6.2 Electronics Package Test and Repair

The electronics package used in previous CODAC and LOMAC experiments has undergone

many changes and alterations since its initial design and creation by Douglas Guardino. This

package consists of multi-axis accelerometers, a GPS sensor, an optical inclinometer and a

compass heading sensor which transfer data wirelessly to any Wi-Fi enabled computer. This data

is then received by a program such as Telnet or Hyper Terminal and is stored in a text file. This

data can then be analyzed using Excel or MatLab. Currently due to the efforts of Eduardo

Gonzales the package has been placed in a water-proof case to avoid further water damage to the

electronics.

Figure 6.2.1: Electronics package for data acquisition in new waterproof case

Such damage may have occurred last year on the displacement catamaran project and hence has weakened the package as a whole. When first receiving the package the GPS antenna connector had to be adjusted in order to get a valid GPS signal to obtain velocity and position data, also lack of such a signal undermines the data transfer of the whole package. Once adjusted and with all the components replaced into the case, the package was ready for a land based test to ensure correct functioning of the data acquisition and transfer. This land test indicated that the package itself was very unreliable transmitting only at random times. For this reason the package could not be fully relied upon for the data acquisition. In order to obtain more accurate and consistent data a new electronics suite should be purchased, smaller in size and with data-logging abilities to eliminate the need for a laptop in the field.

6.3 Pre-Run Checklist/Procedures

In order to run the boat effectively and smoothly a series of procedure have to be followed prior to the starting of the data trails. Following these steps will ensure a safe and efficient running of the vehicle.

1. Turn on data acquisition package
2. Install data acquisition package on frame and secure
3. Undo engine hatch wing nuts
4. Undo rear bolt on front slider
5. Pull up engine hatch
6. Fill up gas tanks
7. Check operation of servos/electronics
8. Prime motors
9. Put pre-heater on starboard engine
10. Start starboard engine
11. Reduce starboard engine to idle
12. Remove pre-heater
13. Repeat 7-10 for port engine
14. Visually inspect bilges for leaks/malfunctions
15. Close engine hatch ensuring the water exhaust go over deck
16. Replace hatch wing nuts
17. Replace front slider bolts
18. Walk boat into water

6.4 Data Acquisition/Logging

With the package turned on the accelerometers and GPS sensors emit data continuously over wireless LAN. In order for the laptop to receive the data strings it must be connected to the wireless network called "*Local*". Once connected using Telnet on the laptop define the file in which to store the data by entering the following command:

set logfile **x**.txt

Where x is the name of the file in which the computer will log the received data. Once this file is defined the data is accessed by using the package's IP address through the following command:

open 192.168.1.50

This will open the IP address of the electronics package and display the data on the screen real-time as well as storing the data in the log file as specified earlier. Once complete the IP address may be closed using the "Ctrl +]" command (ie. Simultaneously holding the Ctrl and + keys)

7.0 Testing Results

To test the CODAC prototype, the wave making atmosphere had to be proportional to the scale model version. The analysis had to be in a semi-controlled atmosphere to achieve this. Although a fully controlled atmosphere did not exist, a similar atmosphere was a small pond in Rhodes Park, West Melbourne, FL. In preparing our prototype the team had to take appropriate measures

to insure that both motors could be started and the hatch cover could be fastened securely. The team created the checklist in section 6.3 and unbolted the hatchback and attached the instrumentation system to the bridge section. With one person holding the bridge and instrumentation package, two others started the engines by inserting the glow plug starter and starting the engine. In doing this each motor was ignited individually and after both were started the hatch would then be lowered and secured. Then from there the boat would be lifted and placed in the water were the computer would start logging data as it was operated. Unfortunately this process did not work out as planned and during the initial try both motors were started but as the hatch was being lowered the port side muffler was compromised and the motor mount screws loosened. This resulted in the team trying to save the exhaust but because of the numerous times the team had tampered with it the screws were stripped. In the end, the team was unable to re-secure the port side engine. Because of the engine slippage, the shaft was then compromised and was unable to function from that time on.

Figure 7.1: Josh attempting to re-secure the loosened motors

Additionally, the instrumentation package successfully connected to the team's computers, but evident corrosion on the wires prevented any data from being taken. Despite the fact that Gonzalez did short-term repairs, the package needs a lot of refurbishment if it is to be considered reliable.

Figure 7.2: Bob frustrated at the corrosion

8.0 The Future of the CODAC

8.1 Recommendations

To complete any testing of the CODAC the main priority is to repair the instrumentation package. Currently, from prior corrosion the instrumentation package does not transmit any data. Without this package testing cannot continue. Therefore, the priority should be to focus its attention toward the repair and continued maintenance of the instrumentation package.

As for CODAC, a more reliable driveshaft system is required. The team recommends using a solid shaft that has a universal joint built in. The original shaft recommended for the engine malfunctioned and its design encompasses a form of a tightly wound spring rather than a solid

shaft design. The soiled shafts with universal joints are commonly found on gas powered RC cars. These shafts could easily be modified for use in the CODAC.

Since the engines produce such high RPMs of around 20,000 to 60,000 the entire vessel undergoes extreme vibrations. The future goal would be to reduce the vibrations experienced by the vessel. One possible solution would be to remount the engines onto a rubber buffer to dampen the accelerations of the engines. To do this the existing engine mounts would have to be redesigned to accommodate an addition of rubber buffers.

Also, to allow for an easier control of operation speeds, the additions of a clutch and transmission systems would allow the driveshaft to operate at lower RPMs. However, since these additions would most likely be a large portion of ones budget they may have to be sacrificed. On the other hand, if capitation became a problem, lower RPMs would reduce the amount of capitation.

The bridge and tunnel sections can accommodate almost any pontoon and instrumentation designs. Therefore a possible continuation with the bridge and tunnel sections could be to create a hydrographic ROV. To complete this, the instrumentation package would have to be repaired and then interfaced with a DC (direct current) bottom sounder, or the bottom sounder would have to record a time with each depth. If the bottom sounder is interfaced with the instrumentation package it would allow for the transmission of longitude, latitude, time, and depth. By analyzing that data a seafloor surface could be rendered using MatLab.

8.2 Future Studies

There are many possibilities for the future of the CODAC, and the LOMAC also. Repair on the damaged electrical and mechanical systems of the CODAC must be completed first, and several spots must be further water-proofed. A basket must be designed to properly hold the instrumentation package at all hull spacings. Additionally, the Guardino/Gonzales instrumentation package has many connections and wires that are rusted to due age and water damage. Finally, the bridge section can be fit to the LOMAC by unbolting it from the CODAC decks and creating a similar deck for the LOMAC.

After these are completed, systematic testing can be done on the CODAC finding the accelerations at every notch in the cams. Then this can be repeated with the tunnel section to see if the tunnel has a dampening effect. These tests should be repeated on the LOMAC in similar conditions. Finally, a formula can be found for each type of hull, planing and semi-displacement, to find the optimum spacing and be scaled to full-size vessels.

Another test is measuring the turning radius of each the LOMAC and CODAC and different hull spacings. Brendan Keane's Masters Thesis strain gages could also be used to measure drag at different hull spacings on each hull. Overall, there is manufacturing, design, and research work to do comparing the planing and semi-displacement hulls.

9.0 Conclusions

Overall, the CODAC team completed everything possible in the given time frame. Although successful data acquisition could not be completed due to mechanical failures, this MFP project

did meet the goals of learning how to work in teams, developing a unique design, using current software, becoming machine shop certified, and building the project. The groundwork has been laid for valuable research of planing and displacement hull catamarans. Hopefully, next year's Naval Architecture group can successfully compare the LOMAC and CODAC and develop a formula to be published. What is most important, however, is that the CODAC team learned how to work independently and gain real engineering experience that will be a large influence in a professional engineering career.

10.0 References

Cengel, Yunus A. Fluid Mechanics: Fundamentals and Applications. 2006

Danielson, et al. 2006 Naval Architecture MFP Final Report

FLYBOAT, June 5 2007, http://www.flyboat.co.uk/orange.JPG

MARINE PERFORMANCE/RACE ENGINES, June 5 2007,

    http://www.bakerengineeringinc.com/images/Big%20Picts/Cat_Can.jpg

Appendix A: Gantt Chart

ID		January 2007										February 2007							March 2007									April 2007										May 2007		

Brainstorm — Tyler ,Stephanie,Josh ,Bob

Initial Design/ CAD Modeling

CNC Programing

Purchas

CNC

Gantt Chart

ID: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21

Timeline: June 2007 (9, 12, 15, 18, 21, 24, 27, 30) | July 2007 (2, 5, 8, 11, 14, 17, 20, 23, 26, 29) | August 2007 (1, 4, 7, 10, 13)

Tasks:
- Website Creation — Tyler, Josh
- ...chasing (Purchasing)
- Logo Design Stickers — Stephanie — Tyler, Stephanie, Josh, Bob
- Stephanie
- CNC Machining — Tyler, Josh
- Hull Sanding — Bob, Stephanie
- Hull Painting — Bob
- Welding — Tyler, Josh
- Bridge Assembly — Tyler, Josh — Tyler, Josh, Ed Robbins
- Tunnel Section Assembly — Josh, Tyler
- Electronics/Engine Instulation — Bob
- Engine Breakin
- Redesign of Driveshaft — Josh, Tyler, Bob
- Redesign of Exhaust — Tyler, Josh

Note: Current Gantt Chart on CD

48

Appendix B: Bill of Materials

Note: All student and consulting hours attached in CD form

Items	Company	Quantity	Price	Total
In line-fuel filters	Space Coast Hobbies	2	3.74	7.48
blue fuel filters tubing	Space Coast Hobbies	2	2.66	5.32
Standard Servos	Space Coast Hobbies	2	12.99	25.98
Fuel tanks	Space Coast Hobbies	2	12.75	25.5
Shaft and casing	Space Coast Hobbies	1	5.46	5.46
High torque servos	Space Coast Hobbies	2	29.99	59.98
O.S .18CVR Mx Marine	Space Coast Hobbies	2	159.99	319.98
75 MHz Fm Receiver	Space Coast Hobbies	1	47.99	47.99
hole punch	Wal-Mart	1	5.72	5.72
erasers	Wal-Mart	1	2.74	2.74
binders	Wal-Mart	1	2.64	2.64
index divider	Wal-Mart	1	1.17	1.17
Batteries	Wal-Mart	1	10.52	10.52
mechanical pencils	Wal-Mart	1	5.87	5.87
Ruler	Wal-Mart	1	2.44	2.44
Largo blue paint	Lewis Marine	1	21.7	21.7
Primer	Lewis Marine	1	16.23	16.23
I gal. 15% Fuel	Space Coast Hobbies	1	15.59	15.59
Os A3 Glow Plugs	Space Coast Hobbies	2	4.94	9.88
Air filter	Space Coast Hobbies	2	4.95	9.9
250cc fuel bottle	Space Coast Hobbies	1	6.25	6.25
fuel tubing	Space Coast Hobbies	2	2.66	5.32
flush pump	Space Coast Hobbies	1	13.59	13.59
Glow starter	Space Coast Hobbies	1	16.96	16.96

After run oil	Space Coast Hobbies	1	2.69	2.69
Plug wrench	Space Coast Hobbies	1	5.81	5.81
Marine sealants	West Marine	2	7.89	15.78
O.S .18 Muffler	Space Coast Hobbies	2	13.99	27.98
header gasket	Space Coast Hobbies	2	1.58	3.16
Fm Rx Crystal	Space Coast Hobbies	1	10.99	10.99
Exhaust deflectors	Space Coast Hobbies	2	3.5	7
Alloy engine mounts	Space Coast Hobbies	2	15.73	31.46
Screw kit engine mounts	Space Coast Hobbies	2	2.47	4.94
Flex drive cables	FunRCBoats.com	2	25.99	51.98
prop dogs	FunRCBoats.com	2	4.5	9
motor couplers	FunRCBoats.com	2	13.95	27.9
Shaft stuffing tube	FunRCBoats.com	2	7.59	15.18
Sheet metal	Alro Metals	1	261.08	261.08
2" tracks	McMaster Carr	1	30.59	30.59
1.75" tracks	McMaster Carr	1	31.77	31.77
Brochures Copy Center	FIT Copy Center	20	0.17	3.4
Fasteners Various	Ace Hardware	1	63.44	63.44
Fasteners Various	Ace Hardware	1	58.06	58.06
Sintra Plastic Sheet 1/4"	Plastics Design	1	61.56	61.56
Boat logo	Boat US	1	23.23	23.23
Boat Letter Kit	West Marine	1	8.59	8.59
Fasteners Various	Ace Hardware	1	68.42	68.42
Rubber Gasket	Ace Hardware	12	4.29	51.48
Paint Thinner	Ace Hardware	1	4.49	4.49
Air Hose Connector	Ace Hardware	1	1.79	1.79
220 Sandpaper	Harbor Freight Tools	1	1.99	1.99

Item	Company	Quantity	Price	Total
150 Sandpaper	Harbor Freight Tools	1	2.49	2.49
Gravity Air Gun	Harbor Freight Tools	1	16.99	16.99
Return Air Filter	Space Coast Hobbies	-2	4.95	-9.9
Solder Kwik Link	Space Coast Hobbies	1	5.45	5.45
Air Filter	Space Coast Hobbies	2	16.11	32.22
Push Rod w/ kwik link	Space Coast Hobbies	4	0.72	2.88
Lithium Grease	Ace Hardware	1	2.99	2.99
Fasteners Various	Ace Hardware	1	11.6	11.6
Rubber Sheet	McMaster Carr	1	77.82	77.82
Fasteners Various/paint	Ace Hardware	1	14.96	14.96
Epoxy SPRY paint	Ace Hardware	1	4.29	4.29
Plastic Tubing	Ace Hardware	1	0.58	0.58
Copper Tubbing	Home Depot	1	9.7	9.7

DONATIONS

Items	Company	Quantity	Price	Total
hours labor	Robbins Welding	23	80	1840
1'x3'x.25'' 5051 Al	Robbins Welding	1	25 per sqr ft	75
1'x3'x.125'' 5051 Al	Robbins Welding	2	15 per sqr ft	90
12' square anodized tubing	Robbins Welding	1	30 per 6 ft	60
10' cyl. Anodized tubing	Robbins Welding	1	35	35
2'' L-tubes	Robbins Welding	2	5	10
1'' L-tubes	Robbins Welding	2	1	2
hours labor	Dyer Matlock	6	40	240
Spray paint gun, etc..	Bill Battin	1	11	11

Robbins Mobil Welding

Total Donations $2123

Dyer Matlock

Total Donations $240

Spent		$1700.04
Left		$49.96
Donated Materials		$283
Donated Labor		$2080
Total Worth		$4063.4

CONSULTING

Dr. Stephen Wood	10	100	1000
Eduardo Gonzalez	3	30	90
Bill Battin	2	50	100
Clay Danielson	2	30	60
John Amero	20	50	1000

STUDENT HOURS

Stephanie Groleau	269	30	8070
Joshua Revord	204	30	6120
Tyler Robbins	276	30	8280
Bob Vandedrinck	251	30	7530

Total Hours $		32250

TOTAL		36313.4

Appendix C: Designs

Item: Gear Cam 1 for Retractable Bridge Section

Material used: Aluminum 5052
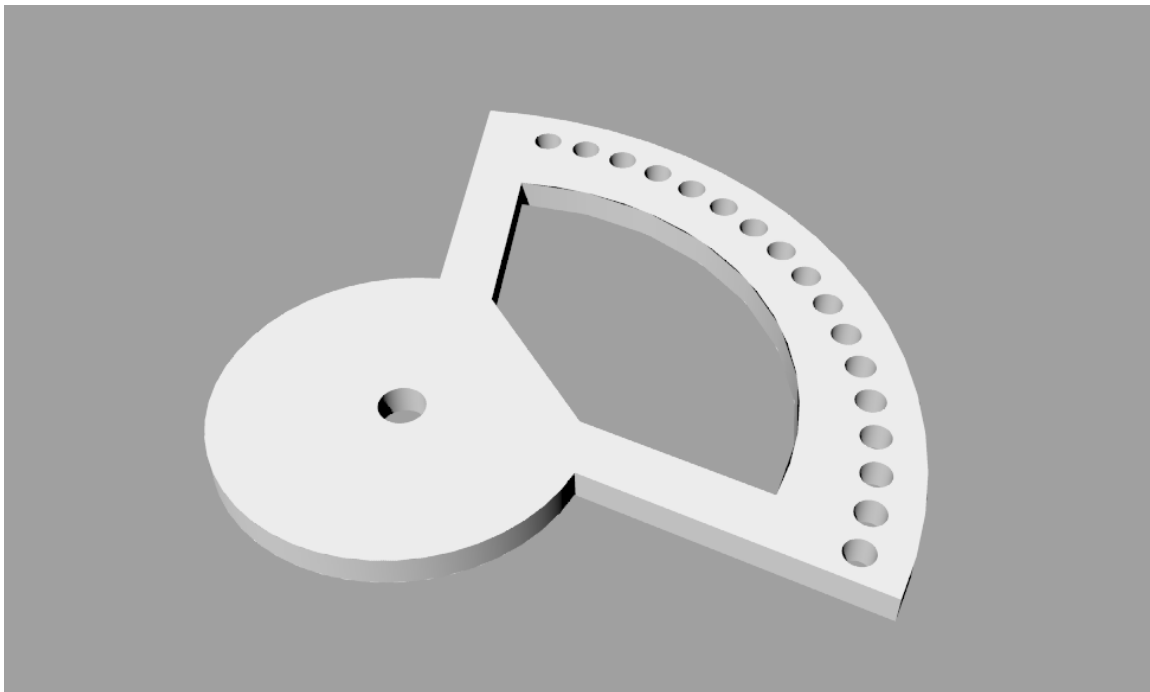
Quantity: 4
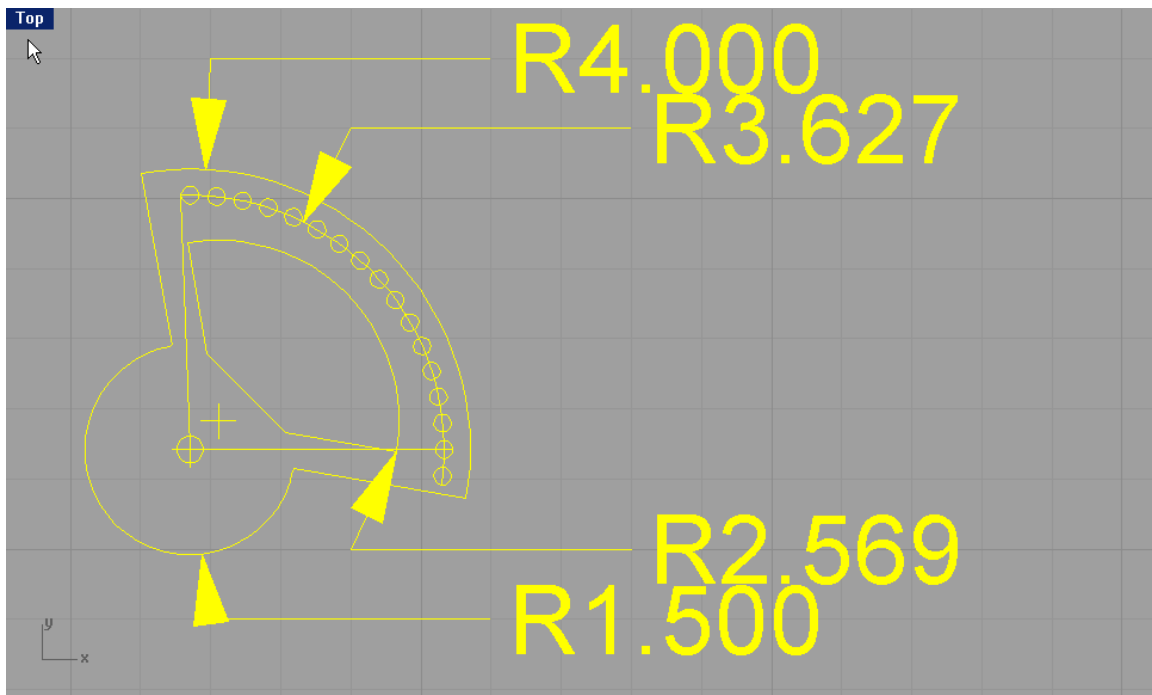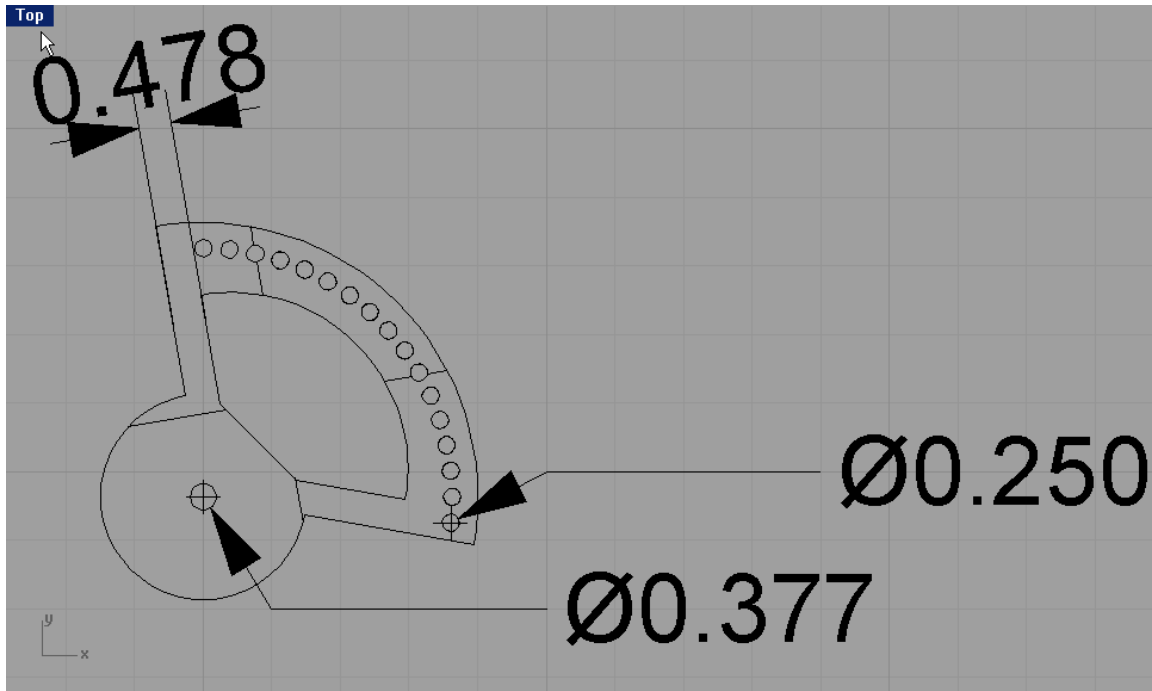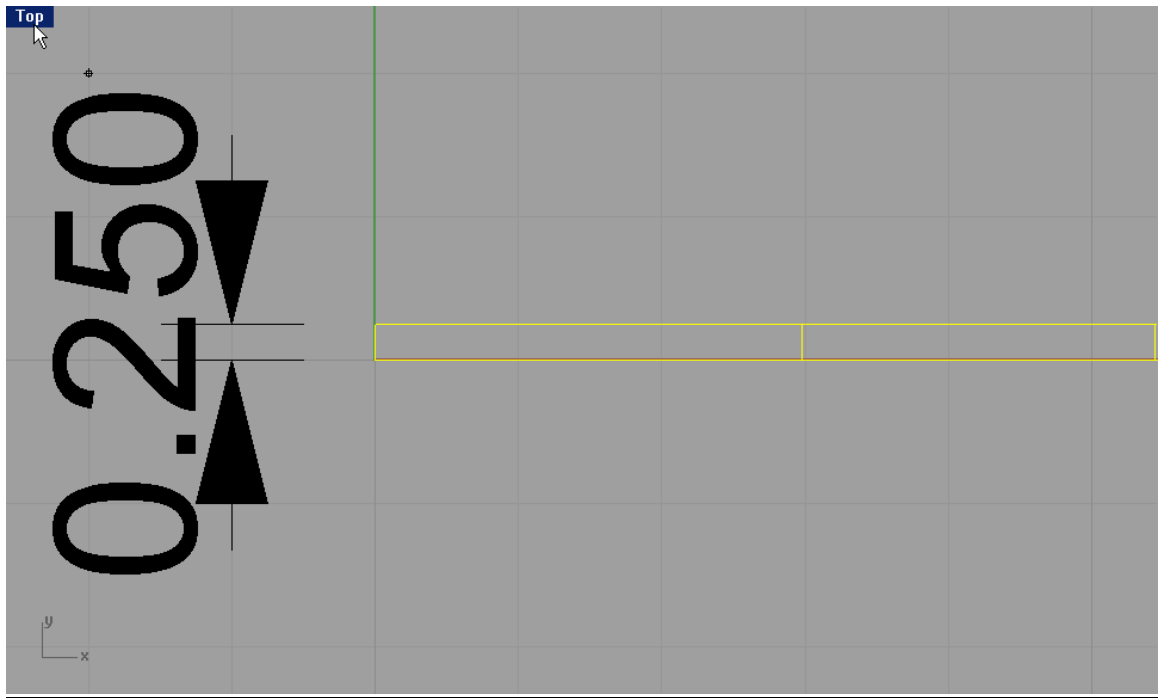
Dimensions:

<u>Item</u>: Gear Cam 2 for Retractable Bridge Section

<u>Material used</u>: Aluminum 5052
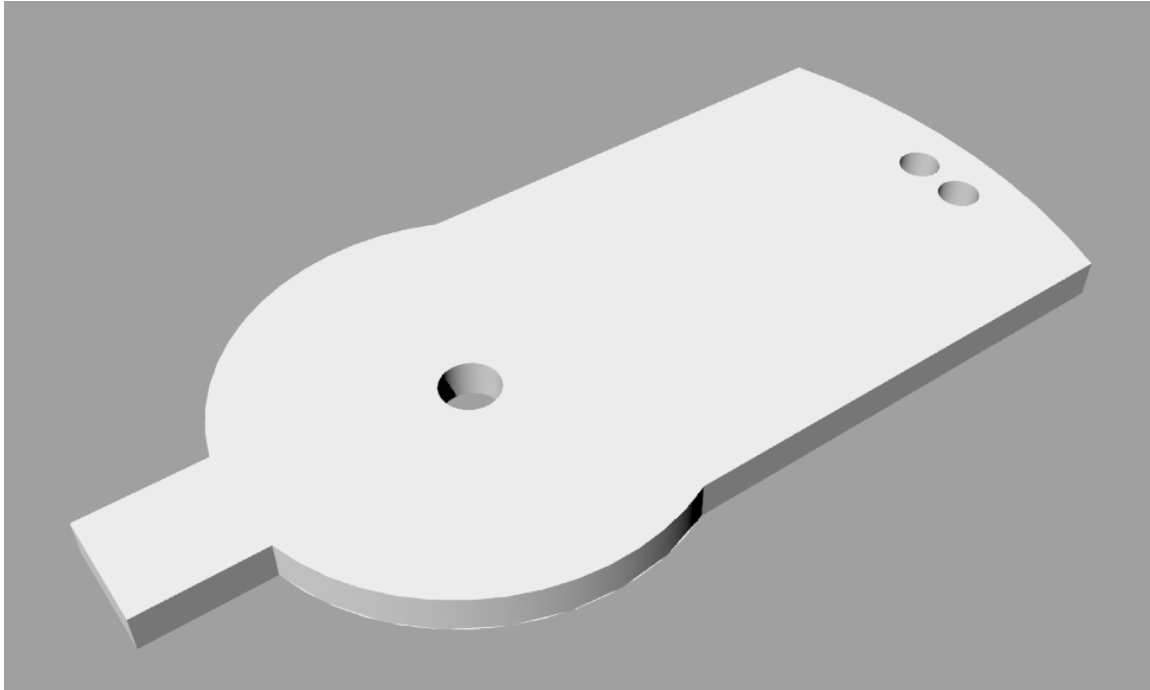
<u>Quantity</u>: 4
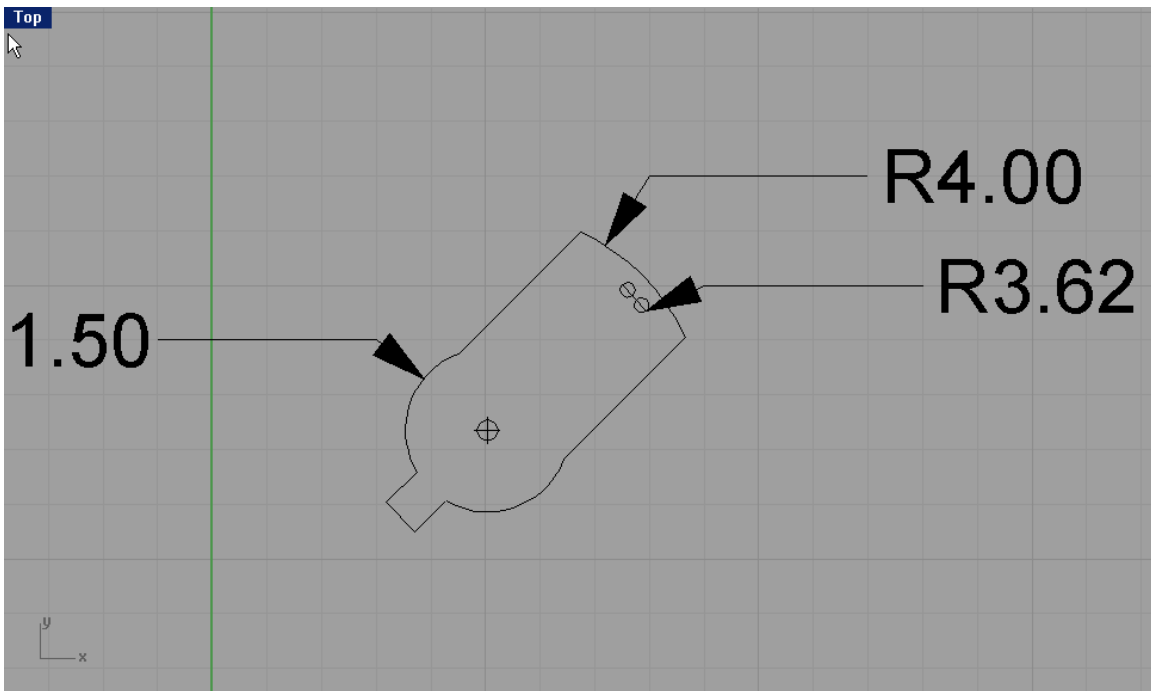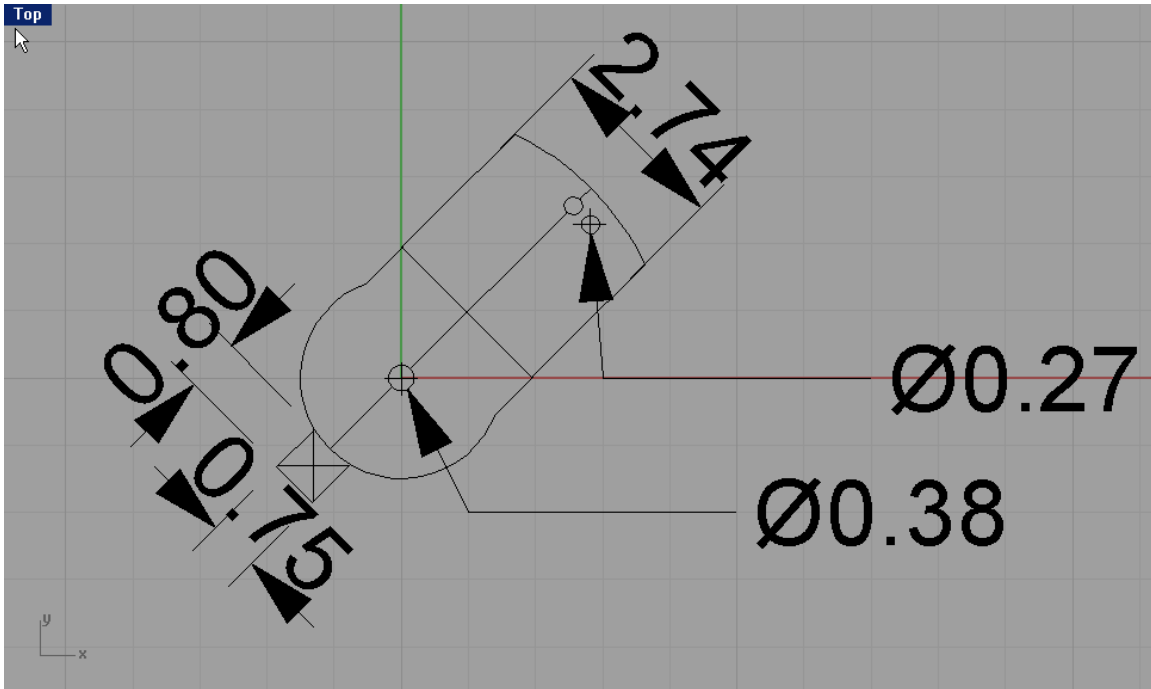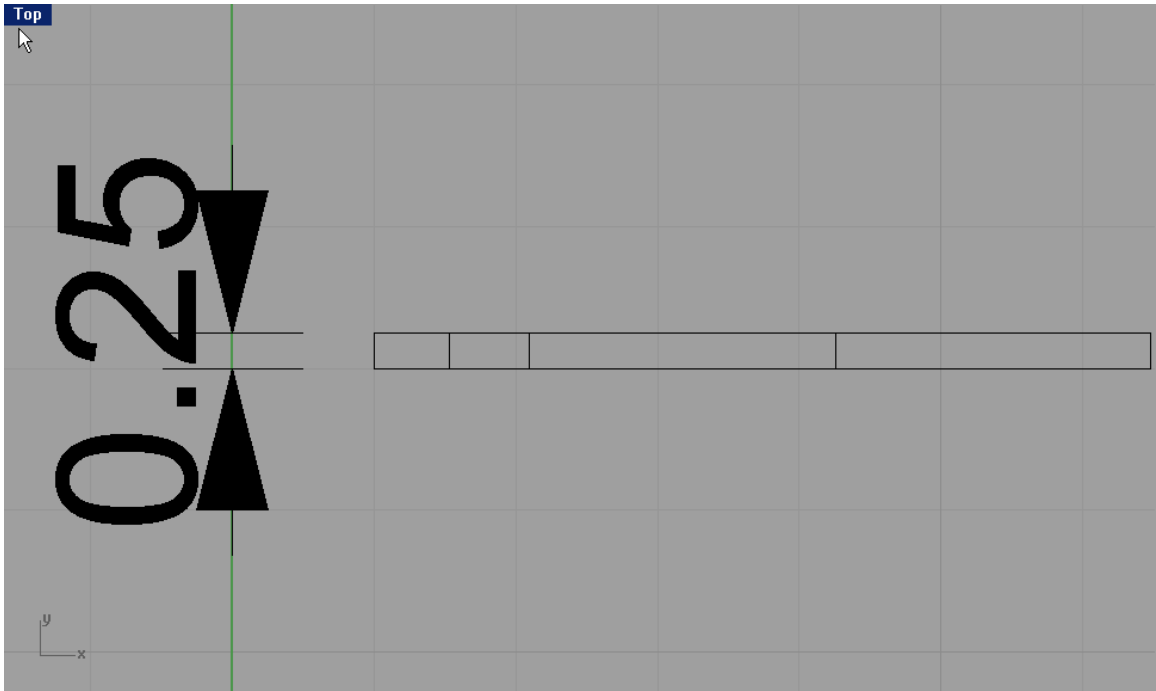
Dimensions:

Modifications to design
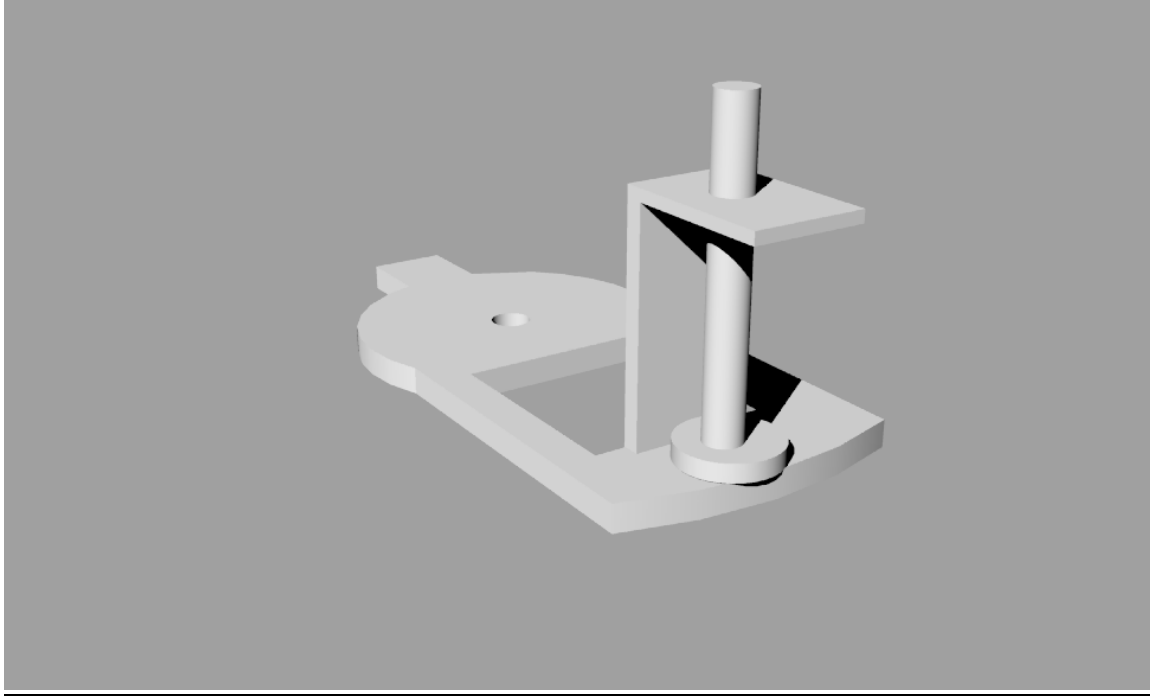
This modification to the design allowed for easy pin connection to the cams. It was spring loaded and welded together.

Item: Hull Stabilizers

Material used: Aluminum 5052 (Base)

Quantity: 4
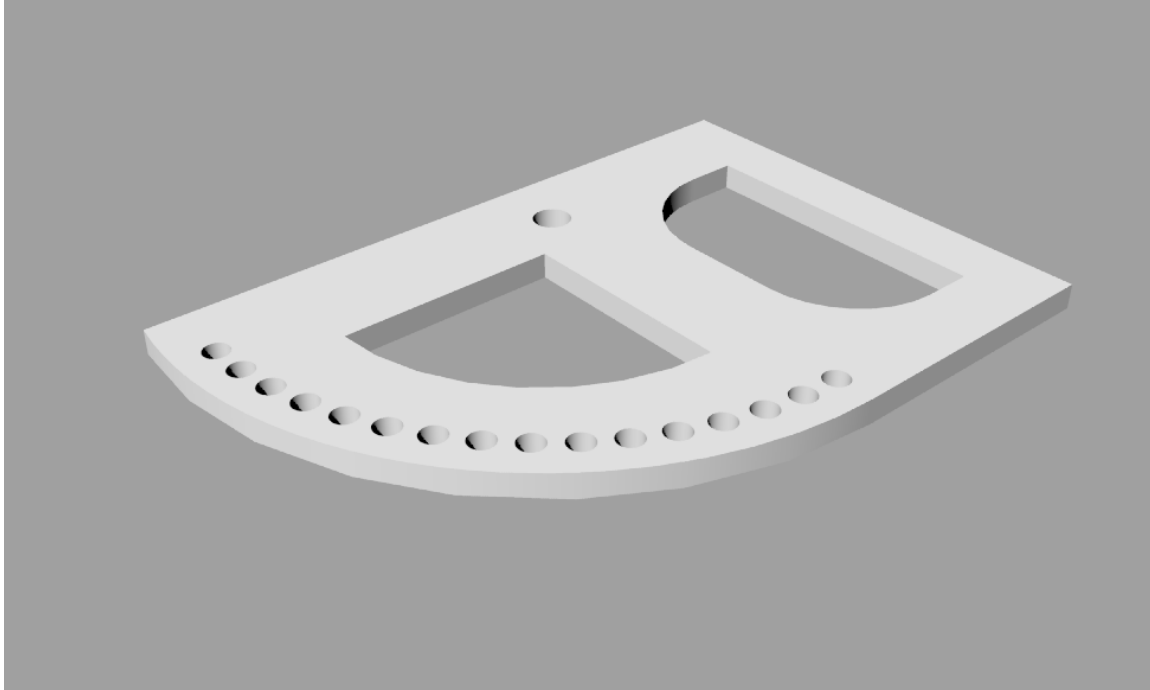
Dimensions:
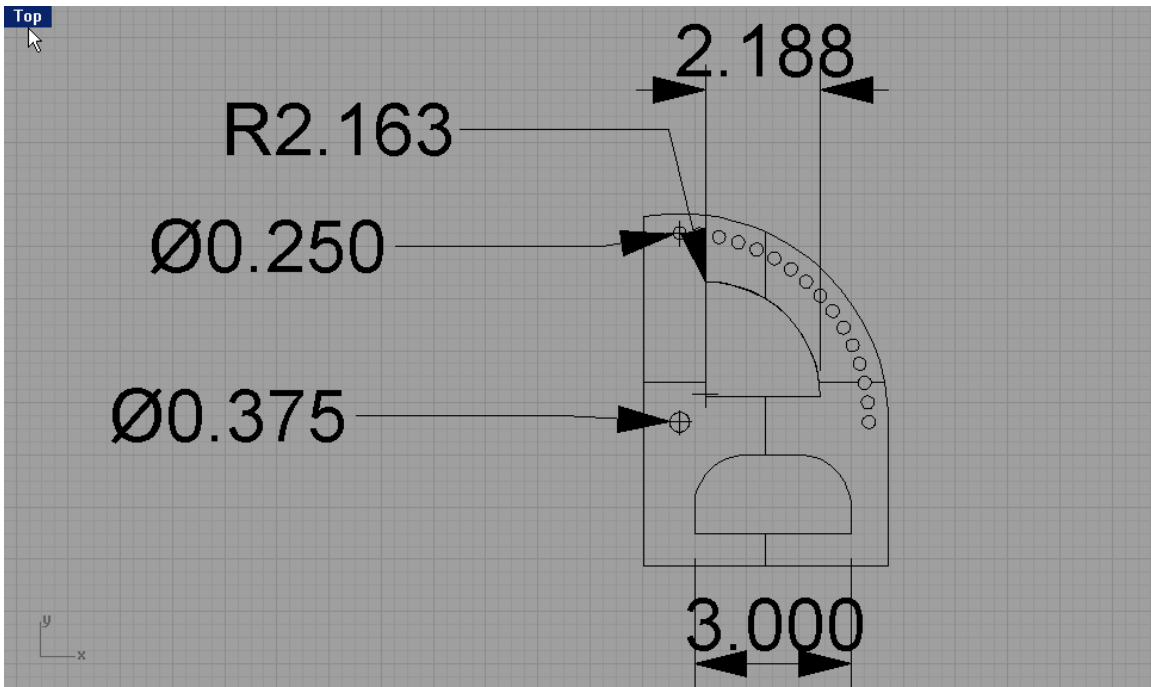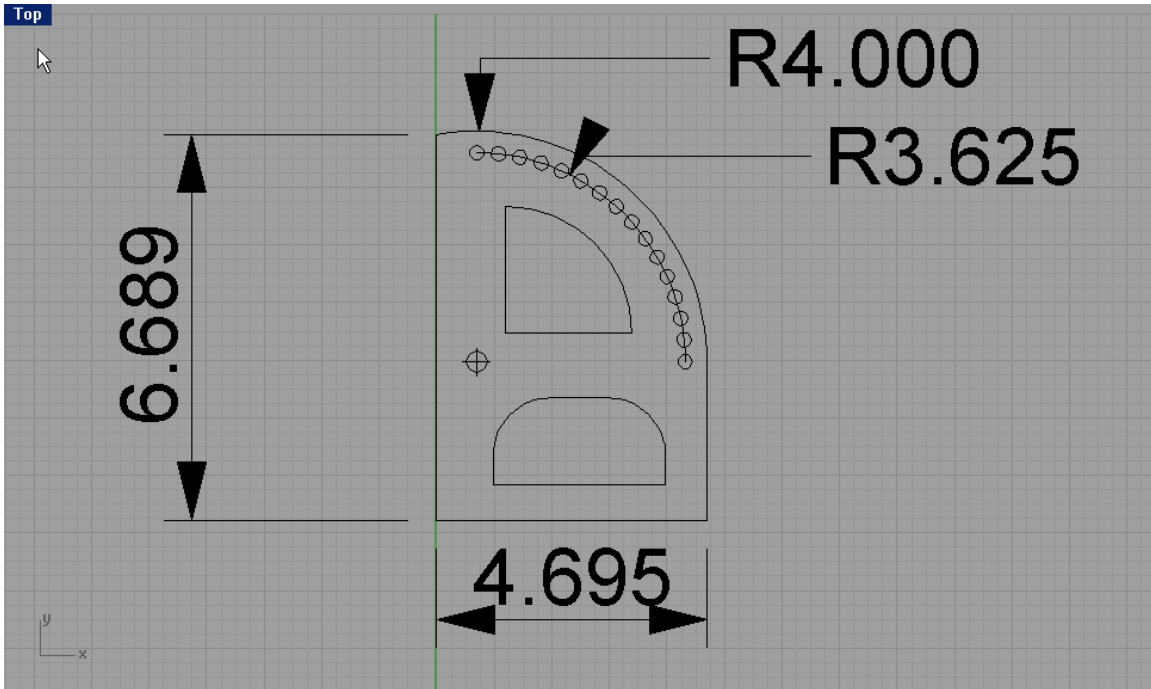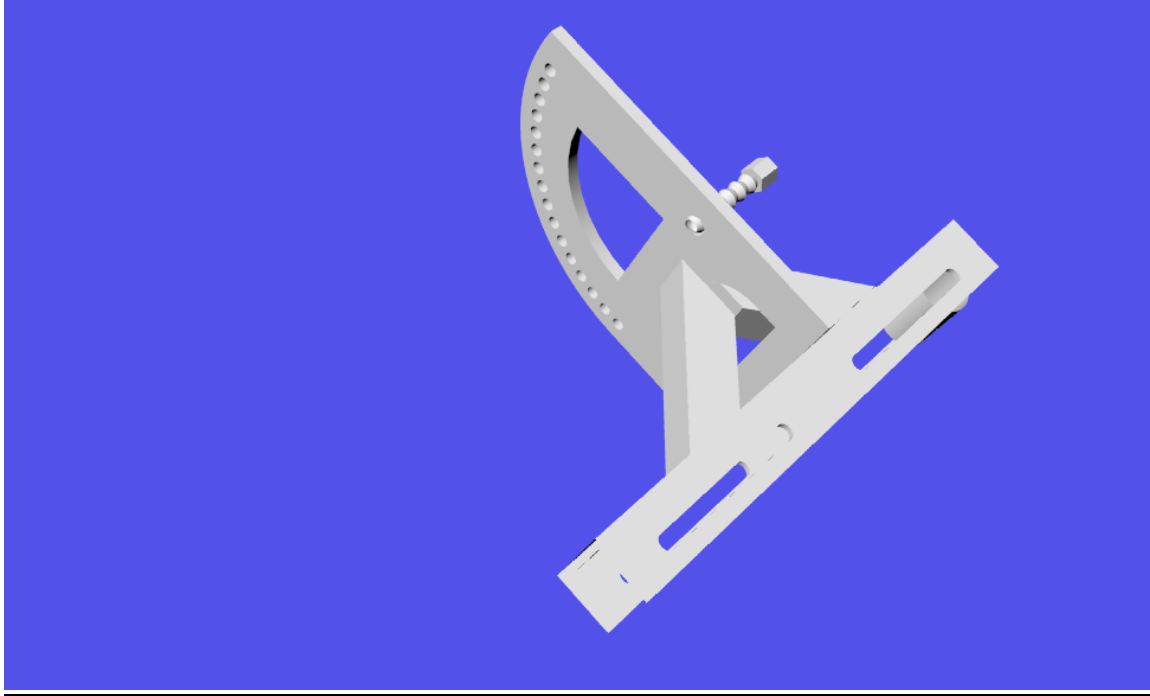
Modification

Item: Extendible Hull Sleeves

Material used: U brackets, Aluminum

Quantity: 4
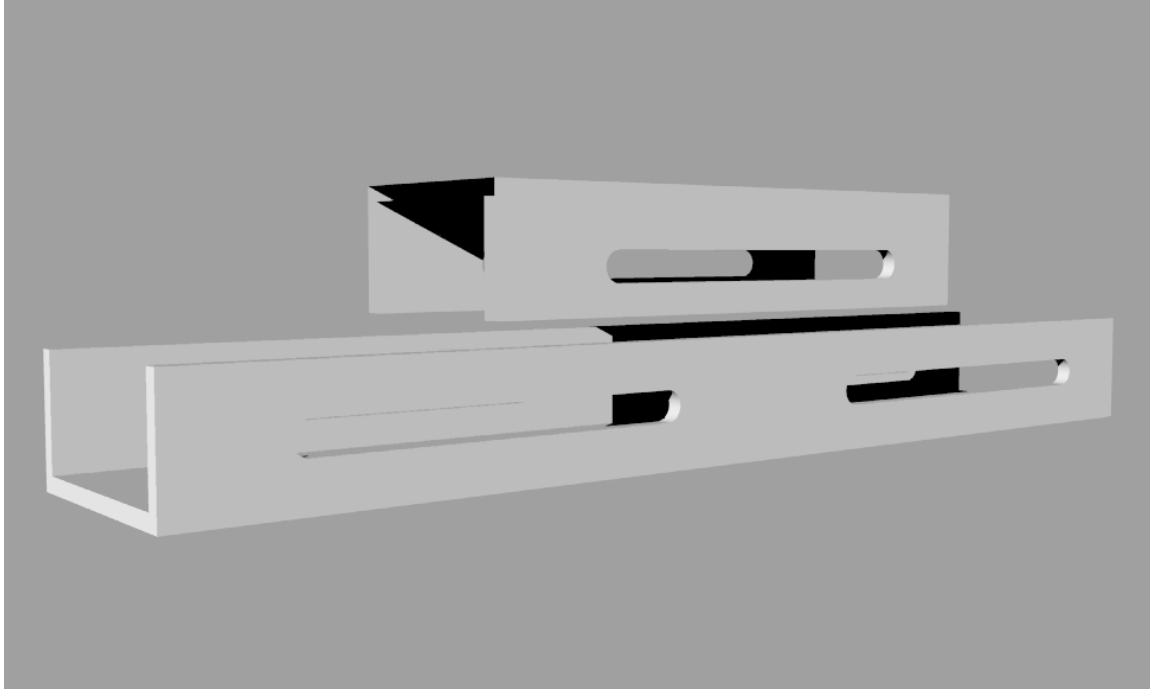
Dimensions
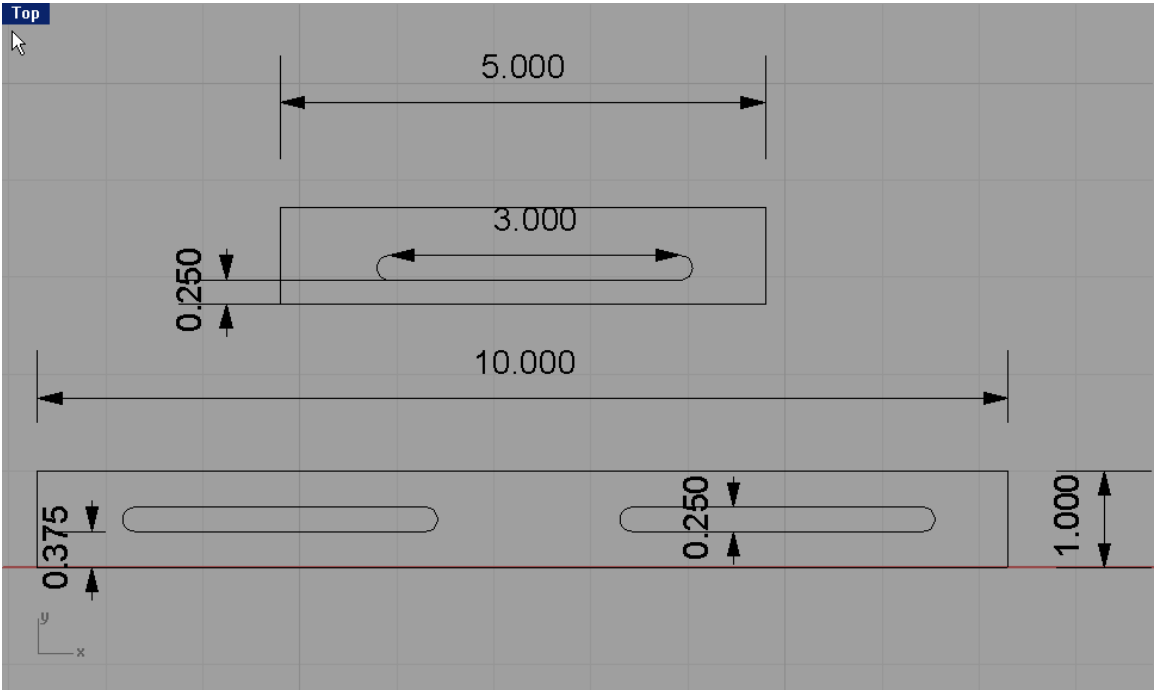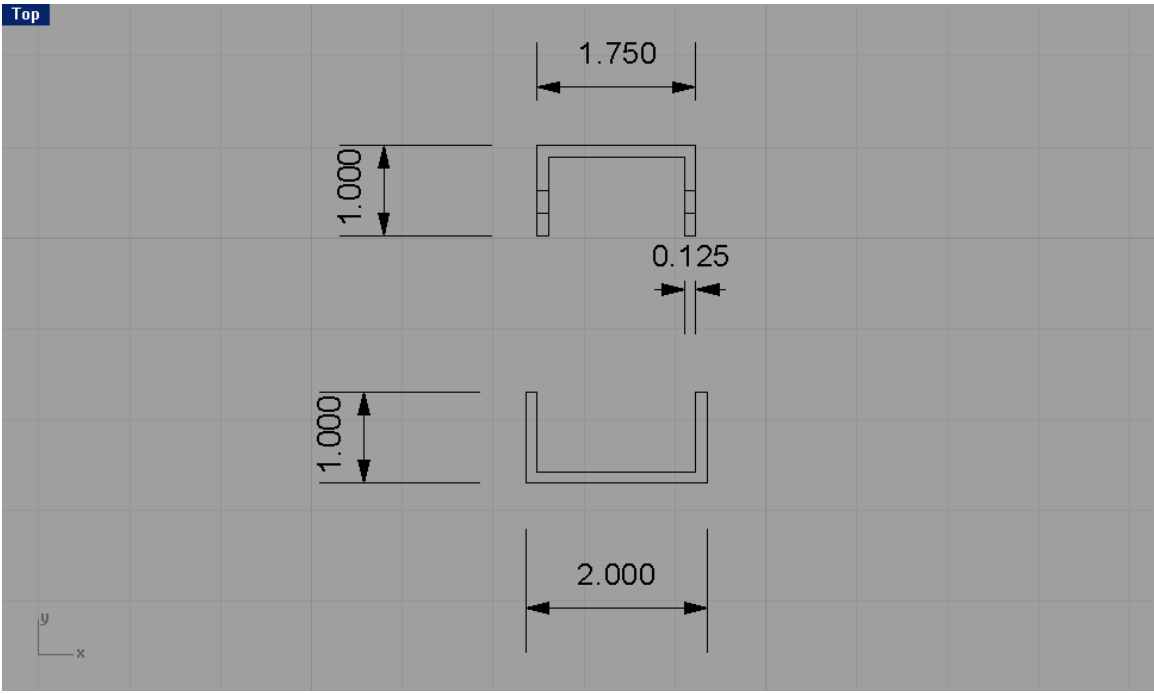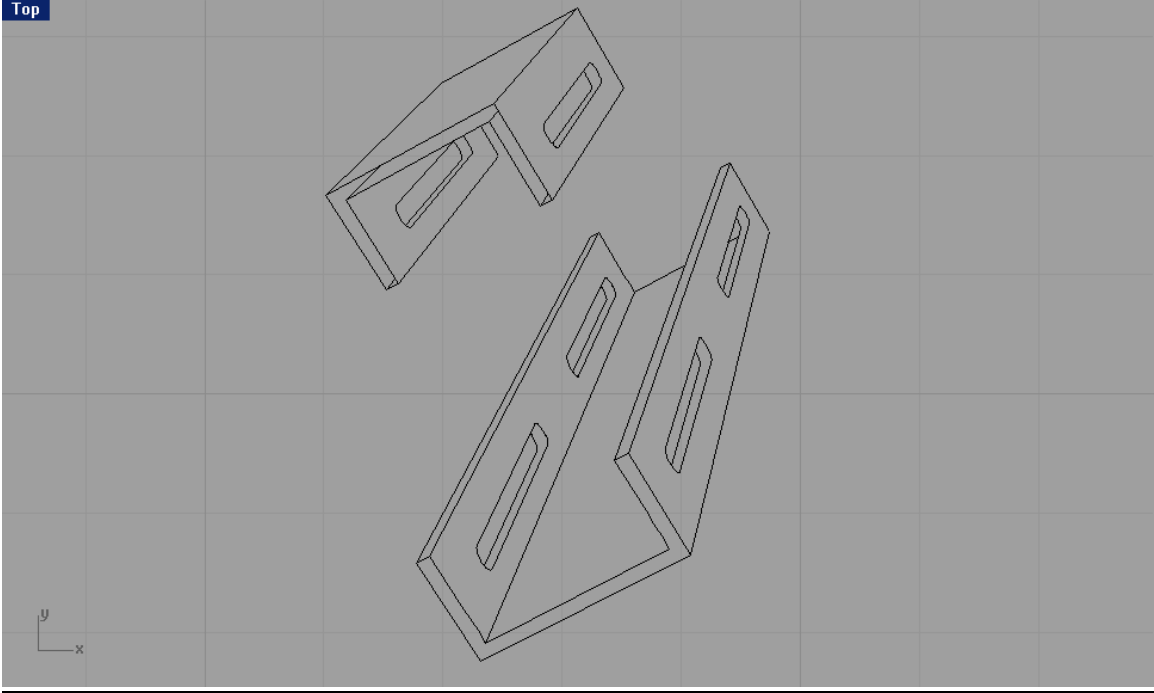
Modification
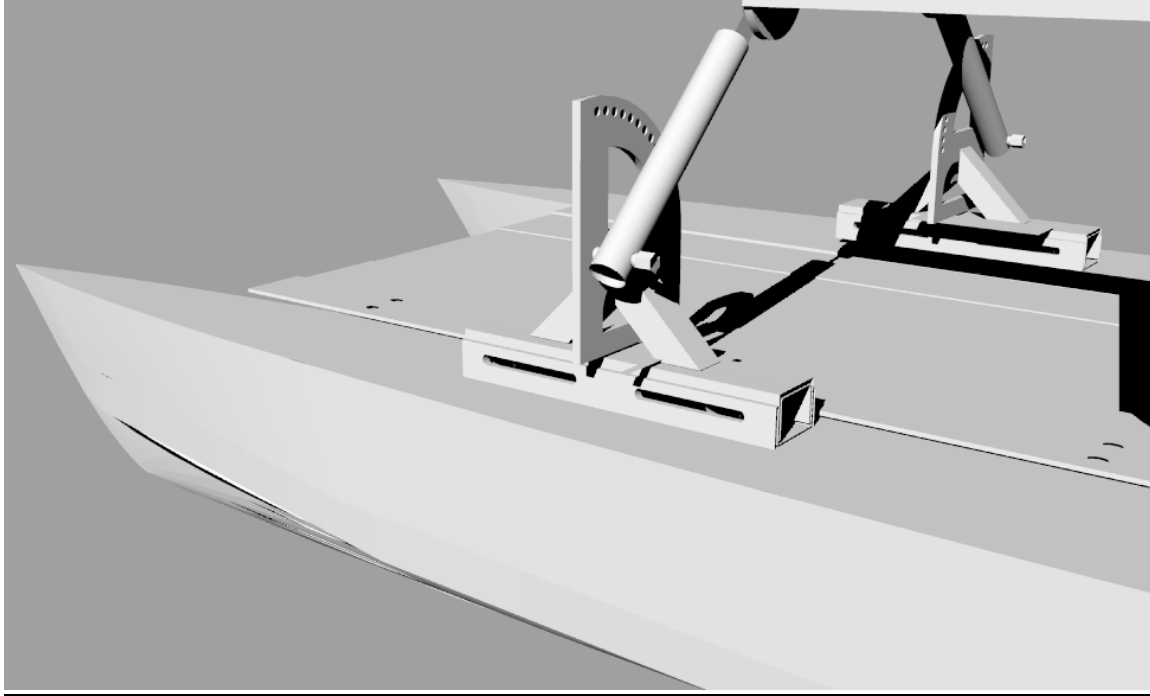
The new design promotes the translation forward and aft of the boat and was created out of two u channels

Item: Retractable Tunnel Section

Material used: Aluminum 5052(Base), 6061 T6 (Sleeves)

Quantity: 4
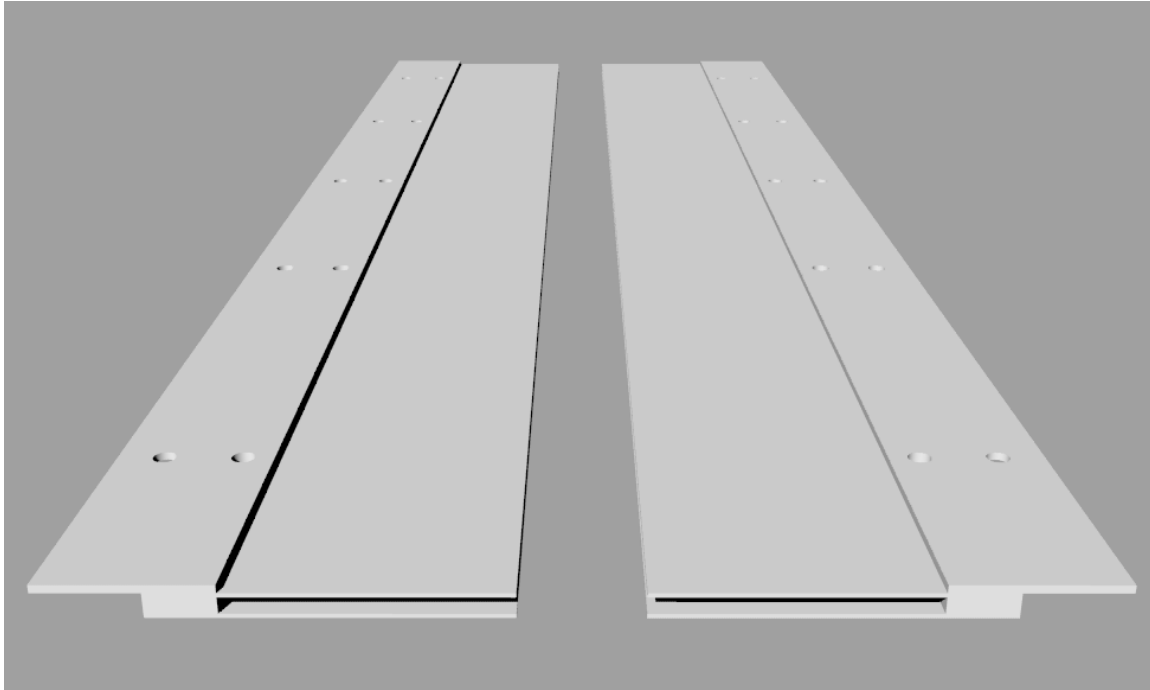
Dimensions:
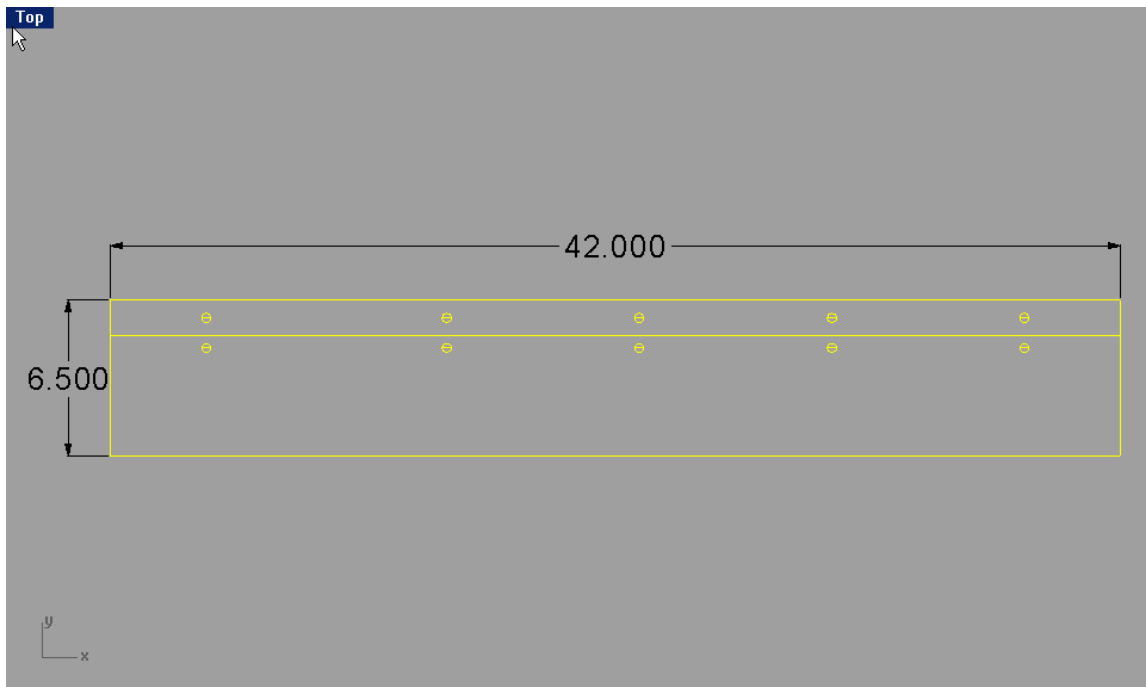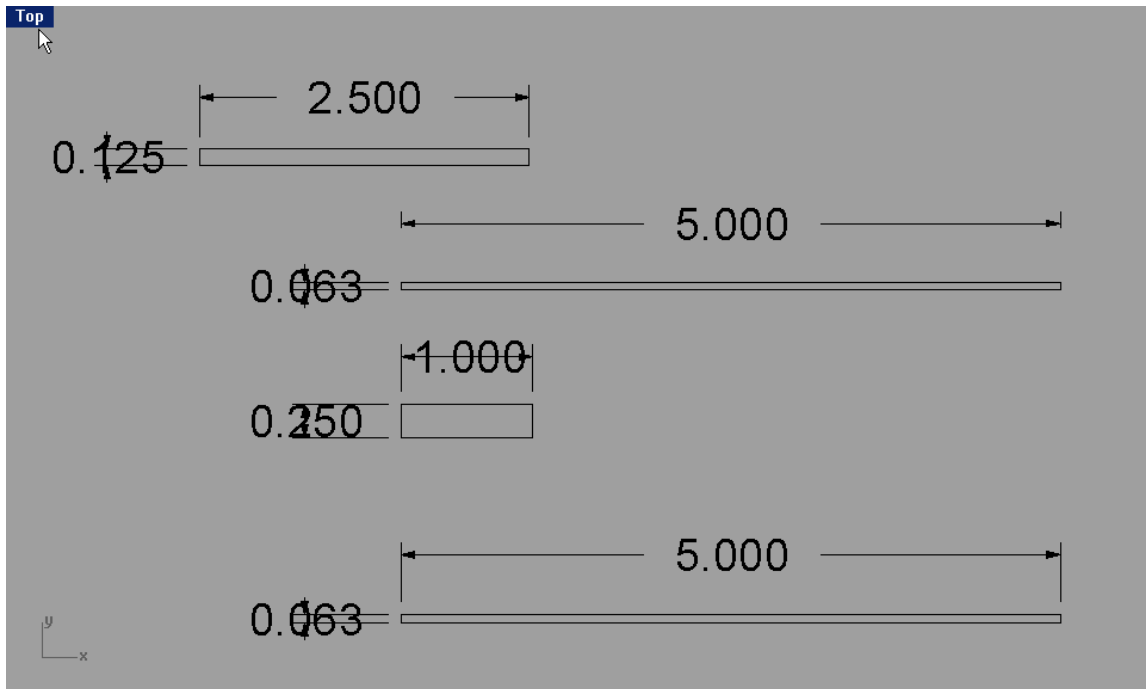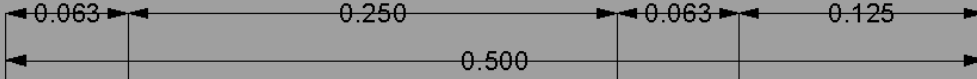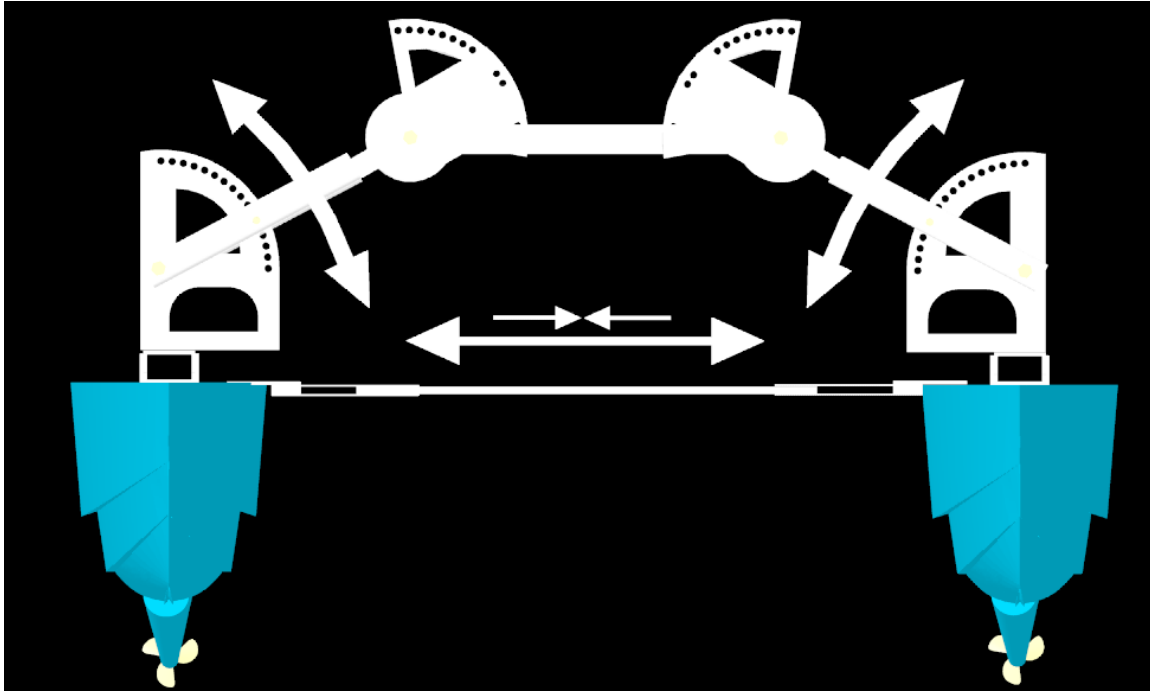
Final Product

The final product of the design allowed for the easy expansion and compression of the hulls and created a dynamic system.
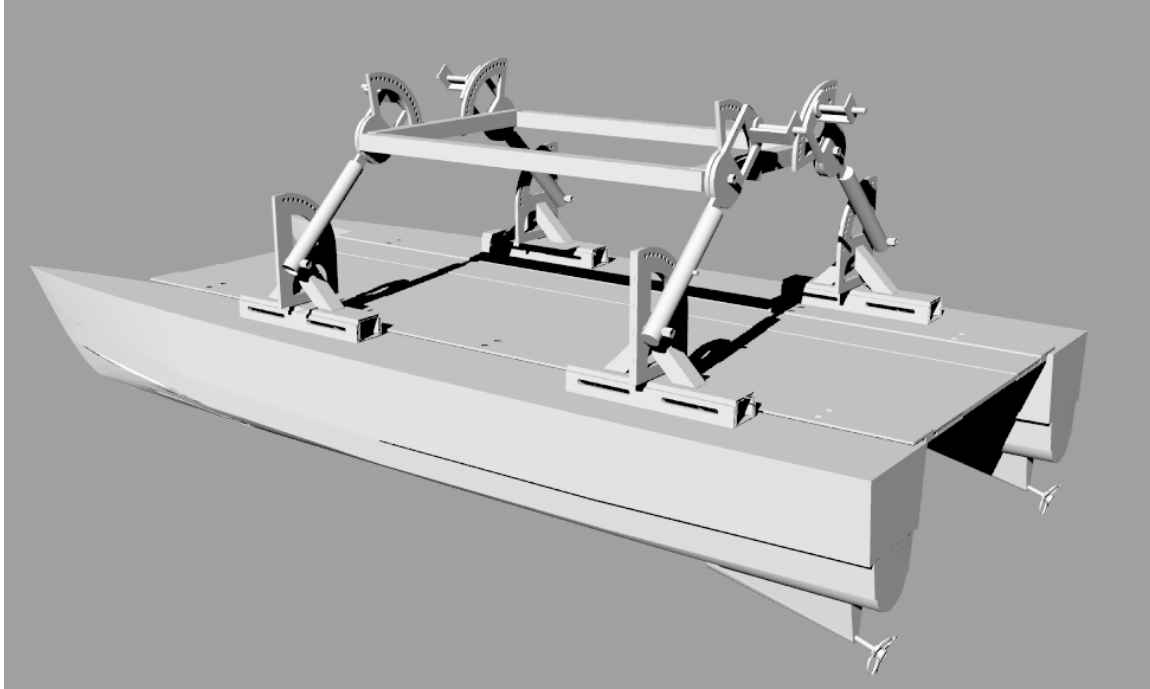
This picture depicts the final render of the design in which we would fabricate
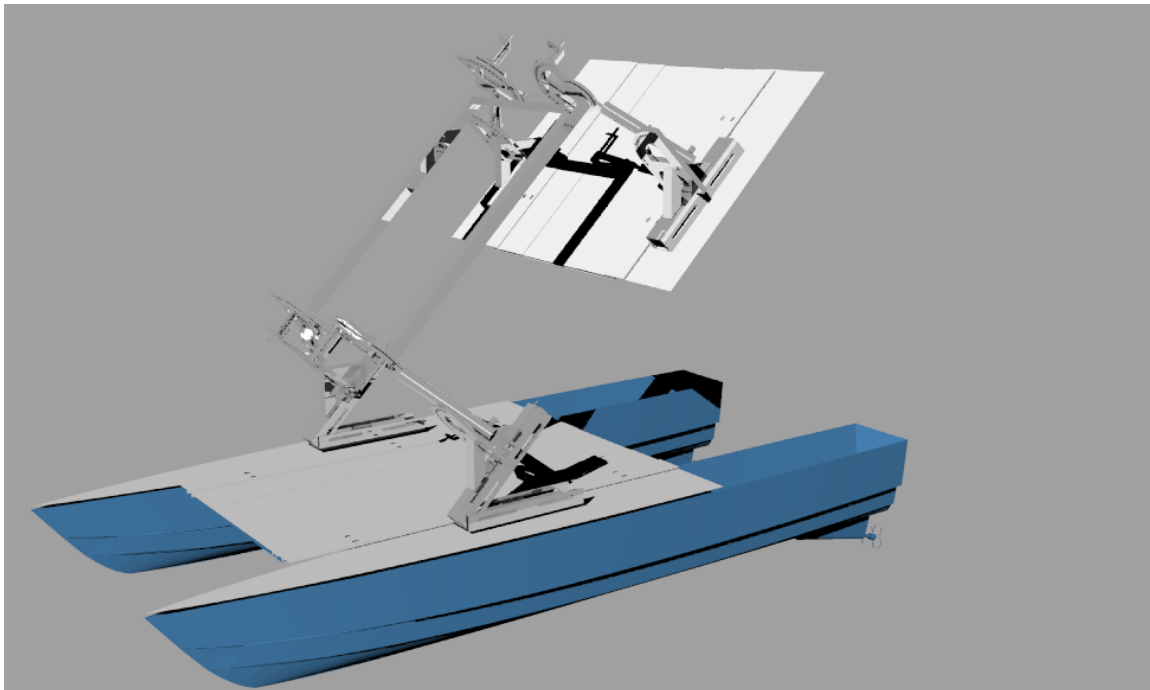
In final production of the decks and tunnel section had to be cut to allow easy access to the motors. This allowed the bridge section to pivot about the front tracks by removing the aft friction bolts.

Appendix D: Accelerometer Program

The following is the accelerometer code by Brendan Keane from the Naval Architecture 2006 MFP final report.

```
#include <p18f458.h>
#include <delays.h>
#include <usart.h>
#include <i2c.h>
#include <string.h>
#include <stdlib.h>
#include <adc.h>
#include <timers.h>

unsigned char status, buffer[80], temp[10];
char charbuff[10], ackstat = 0;
int                     doug, time = 0, timelast;
unsigned long before, after;
rom char        initStMsg[]          =       "Initilazation Status ";
rom char        socketInitStMsg[]    =       "Socket Initilazation Status ";
rom char        WaitConectMsg[]      =          "Waiting for connection";
rom char        conectEstabMsg[]     =       "Connection Established";
rom char   welcomeMsg[]              =       "Good Morning";

// high interupts
void int_handle (void);

#pragma code HIGH_INTERRUPT_VECTOR = 0x8
void high_ISR (void)
{
                _asm
                goto int_handle
                _endasm
}
#pragma code

#pragma interrupt int_handle
void int_handle (void)
{
                WriteTimer0(55535);
                time++;
                INTCON = 0b10100000;
}


// This code is writen assuming a 40MHz Fosc.
```

```c
void i2cTx( unsigned char control, unsigned char addressHigh,
                            unsigned char addressLow, unsigned char *array,
                            unsigned char length)
{
                            unsigned char count;
                            IdleI2C();
                            StartI2C();
                            while ( SSPCON2bits.SEN );
                            control = control & 0xFE;
                            WriteI2C ( control);
                            IdleI2C();
    if ( SSPCON2bits.ACKSTAT )  // test received ack bit state
    {
       ackstat += 1;        // bus device responded with  NOT ACK
    }
                            WriteI2C ( addressHigh);
                            IdleI2C();
                            if ( SSPCON2bits.ACKSTAT )  // test received ack bit state
    {
       ackstat += 1;        // bus device responded with  NOT ACK
    }
                            WriteI2C ( addressLow);
                            for(count = 0; count < length; count++){
                                    IdleI2C();
                                    if ( SSPCON2bits.ACKSTAT )  // test received ack bit state
                            {
       ackstat += 1;        // bus device responded with  NOT ACK
                            }
                                    WriteI2C ( array[count]);
                            }
                            IdleI2C();
                            if ( SSPCON2bits.ACKSTAT )  // test received ack bit state
    {
       ackstat += 1;        // bus device responded with  NOT ACK
    }
                            StopI2C();
                            while ( SSPCON2bits.PEN );
}

unsigned char * i2cRx(   unsigned char control,
                            unsigned char addressHigh,
                            unsigned char addressLow,
                            unsigned char *array,
                            unsigned char length)
{
                            unsigned char count;
                            IdleI2C();
```

```
                        StartI2C();
                        while ( SSPCON2bits.SEN );
                        control = control & 0xFE;
                        WriteI2C ( control);
                        IdleI2C();
                        if ( SSPCON2bits.ACKSTAT )  // test received ack bit state
{
  ackstat += 1;         // bus device responded with  NOT ACK
}
                        WriteI2C (addressHigh);
                        IdleI2C();
                        if ( SSPCON2bits.ACKSTAT )  // test received ack bit state
{
  ackstat += 1;         // bus device responded with  NOT ACK
}
                        WriteI2C ( addressLow);
                        IdleI2C();
                        if ( SSPCON2bits.ACKSTAT )  // test received ack bit state
{
  ackstat += 1;         // bus device responded with  NOT ACK
}
                        StopI2C();
                        while ( SSPCON2bits.PEN );

                        control = control | 0x01;
                        IdleI2C();
                        StartI2C();
                        while ( SSPCON2bits.SEN );
                        WriteI2C ( control);
                        if ( SSPCON2bits.ACKSTAT )  // test received ack bit state
{
  ackstat += 1;         // bus device responded with  NOT ACK
}
                        SSPCON2bits.RCEN = 1;

                        for(count = 0; count < length; count++){
                                IdleI2C();
                                array[count] = ReadI2C();
                                if (count == length -1){
                                        NotAckI2C();
                                }
                                else{
                                        AckI2C();
                                }
                        }

                        IdleI2C();
                        StopI2C();
```

```c
                    while ( SSPCON2bits.PEN );
                    return(array);
}


unsigned char InitWiznet( unsigned char control)
{
                    unsigned char data;
                    // initilise IINCHIP
                    // Gatway Address
                    buffer[0] = 192;                    //80
                    buffer[1] = 168;         //81
                    buffer[2] = 1;                      //82
                    buffer[3] = 1;                      //83

                    // Subnet Mask
                    buffer[4] = 255;                    //84
                    buffer[5] = 255;                    //85
                    buffer[6] = 255;         //86
                    buffer[7] = 0;                      //87

                    //MAC Address
                    buffer[8] = 0x00;                   //88
                    buffer[9] = 0xA0;                   //89
                    buffer[10] = 0x24;                  //8A
                    buffer[11] = 0xBB;                  //8B
                    buffer[12] = 0xD8;                  //8C
                    buffer[13] = 0x6A;                  //8D

                    // IP Address
                    buffer[14] = 192;                   //8E
                    buffer[15] = 168;                   //8F
                    buffer[16] = 1;                     //90
                    buffer[17] = 50;         //91

                    // Initial Retry Timer - value
                    buffer[18] = 0x03;       //92 100ms
                    buffer[19] = 0xE8;       //93

                    //Retry Count
                    buffer[20] = 255;                   //94

                    // RX data Memory size
                    buffer[21] = 0b000011;  //95 8kb to ch 0

                    // TX data Memory size
                    buffer[22] = 0b000011;  //96 8kb to ch 0
```

```c
                //Write all that to the IINCHIP
                i2cTx( control, 0x00, 0x80, buffer, 23);

                buffer[0] = 0x01;

                //Sends the initialze command
                i2cTx( control, 0x00, 0x00, buffer, 1);


                //Checks status of initilazation
                i2cRx( control, 0x00, 0x04, &data, 1);

                //Returns the result of the initilazation
                return(data);
}

unsigned char initSocketCh0(    unsigned char control,
                                unsigned char hport,
                                unsigned char lport)
{
                unsigned char data;
                // set SOPR register
                data = 0x01; //TCP communications
                i2cTx( control, 0x00, 0xA1, &data, 1);

                // set SPR registers, sets the port to listen on
                buffer[0] = hport;
                buffer[1] = lport;
                i2cTx( control, 0x00, 0xAE, buffer, 2);

                // set TOSR register to 1
                // data alreadyt = 1 so it will not be set again
                i2cTx( control, 0x00, 0xB1, &data, 1);

                // set transmisoin pointers
                memset(buffer, 0, 10); // set first 10 buffer locations to 0
                // set C0_TW_PR 01 - 04 to 0
                // set C0_TR_PR 01 - 04 to 0
                i2cTx( control, 0x00, 0x40, buffer, 8);
                // set C0_TA_PR 01 - 04 to 0
                i2cTx( control, 0x00, 0x18, buffer, 4);

                // initilise socket
                data = 0b00000010;
                i2cTx( control, 0x00, 0x00, &data, 1);

                //clear interupts
                data = 0xFF;
```

```c
                    i2cTx( control, 0x00, 0x08, &data, 1);

                    //check if socket initilized
                    i2cRx( control, 0x00, 0x04, &data, 1);

                    return(data);
}

void stringUARTS(char * string, unsigned char length){
                    unsigned char x;
                    for( x = 0; x < length; x++){
                            while (BusyUSART());
                            WriteUSART(string[x]);
                    }
                    return;
}

int reciveData(unsigned char control)
{
                    unsigned char   C0_RW_PR[4], C0_RR_PR[4], data, adhigh, adlow,
                                                rxlength = 0;
                    unsigned int    counter, rstart, rend;


                    memset(C0_RW_PR, 0, 4);
                    memset(C0_RR_PR, 0, 4);

                    // get pointers for recived data
                    //check shadow pointer C0_SRW_PR
                    i2cRx( control, 0x01, 0xE0, &data, 1);

                    //wait 20 clock cycles
                    Delay10TCYx(2);

                    //Get the C0_RW_PR pointers
                    i2cRx( control, 0x00, 0x10, C0_RW_PR, 4);

                    //check shadow pointer C0_SRR_PR
                    i2cRx( control, 0x01, 0xE1, &data, 1);

                    //wait 20 clock cycles
                    Delay10TCYx(2);

                    //Get the C0_RR_PR pointers
                    i2cRx( control, 0x00, 0x14, C0_RR_PR, 4);


                    //Convert pointer into offsets
```

```
rstart = C0_RR_PR[2];
rstart = rstart << 8;
rstart &= 0x1F00;
rstart += C0_RR_PR[3];

rend = C0_RW_PR[2] ;
rend = rend << 8;
rend &= 0x1F00;
rend += C0_RW_PR[3];



//Find lenght of information in buffer
if(rend > rstart){
        counter = rend - rstart;
        data = 0;
}
else{
        counter = (rend + 0x1FFF) - rstart;
        data = 1;
}
if(rend == rstart){
        return(0);
}
rxlength = 0;

while(counter){
        adhigh = rstart >> 8;
        adhigh += 0x60;
        adlow = rstart & 0x00FF;
        if( counter < 80){
                rxlength = counter;
        }
        else
                rxlength = 80;
        if ( (rstart + rxlength) > 0x1FFF){
                rxlength = 0x2000 - rstart;
        }

        i2cRx( control, adhigh, adlow, buffer, rxlength);

        stringUARTS((char *)buffer, rxlength);

        rstart += rxlength;
        if (rstart > 0x1FFF){
                rstart -= 0x2000;
        }
        counter -= rxlength;
```

```
                }
                i2cTx( control, 0x00, 0x14, C0_RW_PR, 4);
                data = 0b01000000;
                i2cTx( control, 0x00, 0x00, &data, 1);
                return(1);
}

void trasmitData(       unsigned char control, unsigned char * string,
                                                unsigned char length){

                unsigned char   C0_TW_PR[4], data, adhigh, adlow, txlength, offset = 0;
                unsigned char * TW;

                unsigned int    counter, tstart, tend;

                unsigned long   C0_TW;

                char                    y;

                TW = (unsigned char *)&C0_TW;

                // get pointers for recived data
                //check shadow pointer C0_STW_PR
                i2cRx( control, 0x01, 0xF0, &data, 1);

                //wait 20 clock cycles
                Delay10TCYx(2);

                //Get the C0_TW_PR pointers
                i2cRx( control, 0x00, 0x40, C0_TW_PR, 4);

                y = 3;

                for(y = 3; y >= 0; y--){
                        TW[y] = C0_TW_PR[3 - y];
                }
                before = C0_TW;
                C0_TW += length;
                after = C0_TW;

                //Convert pointer into offsets
                tstart = C0_TW_PR[2];
                tstart = tstart << 8;
                tstart &= 0x1F00;
                tstart += C0_TW_PR[3];

                while(length){
                        adhigh = tstart >> 8;
```

```
                    adhigh += 0x40;
                    adlow = tstart & 0x00FF;

                    if ( (tstart + length) > 0x1FFF)
                            txlength = 0x2000 - tstart;
                    else
                            txlength = length;

                    i2cTx( control, adhigh, adlow, string + offset, txlength);

                    tstart += txlength;
                    if (tstart > 0x1FFF){
                            tstart -= 0x2000;
                    }
                    length -= txlength;
                    offset += txlength;
            }
            for(y = 3; y >= 0; y--){
                    C0_TW_PR[y]= TW[3 - y] ;
            }

            // Update the C0_TW_PR pointers
            i2cTx( control, 0x00, 0x40, C0_TW_PR, 4);

            // Execute a send comand
            data = 0b00100000;
            i2cTx( control, 0x00, 0x00, &data, 1);

            return;
}

char * asciAcell(int value, char * string){
            int letter;
            if (value < 0){
                    value = value * -1;
                    string[0] = 45;
            }
            else
                    string[0] = 32;
            letter = value / 1000;
            value = value - (1000 * letter);
            string[1] = letter + 48;
            string[2] = 46;
            letter = value / 100;
            value = value - (100 * letter);
            string[3] = letter + 48;
            letter = value / 10;
            value = value - (10 * letter);
```

```c
                                string[4] = letter + 48;
                                string[5] = value + 48;
                                return(string);
}

char * getacell(char chan, char * outputB){
                        int acell;
                        unsigned int acell_16 = 0 ;
                        char x;
                        short long voltage;
                        if( chan == 0)
                                SetChanADC(ADC_CH0);
                        if( chan == 1)
                                SetChanADC(ADC_CH1);
                        if( chan == 2)
                                SetChanADC(ADC_CH2);
                        if( chan == 3)
                                SetChanADC(ADC_CH3);
                        Delay10TCYx(7);
                        for( x = 0; x < 16; x++){
                                ConvertADC();
                                while(BusyADC());
                                acell = ReadADC();
                                acell_16 += acell;
                        }
                        acell = acell_16 >> 4;
                        doug = acell;
                        acell -= 511;
                        voltage = acell;
                        voltage = voltage * 1000;
                        voltage = voltage / 204; //205
                        acell = voltage;
                        asciAcell(acell, outputB);
                        outputB[6] = 32;
                        if( chan == 0)
                                outputB[7] = 90;
                        if( chan == 1)
                                outputB[7] = 89;
                        if( chan == 2)
                                outputB[7] = 90;
                        if( chan == 3)
                                outputB[7] = 88;
                        outputB[8] = 13;
                        outputB[9] = 10;
                        return(outputB);
}

char * getanalog(char * outputB){
```

```c
int NS = 0, EW = 0, power = 0, NS16 = 0, EW16 = 0, power16 = 0, x;
char stringL;
short long voltage;
SetChanADC(ADC_CH4);
Delay10TCYx(7);
for( x = 0; x < 16; x++){
        ConvertADC();
        while(BusyADC());
        NS = ReadADC();
        NS16 += NS;
}
SetChanADC(ADC_CH5);
Delay10TCYx(7);
for( x = 0; x < 16; x++){
        ConvertADC();
        while(BusyADC());
        EW = ReadADC();
        EW16 += EW;
}
NS = NS16 >> 4;
EW = EW16 >> 4;
SetChanADC(ADC_CH6);
Delay10TCYx(7);
for( x = 0; x < 16; x++){
        ConvertADC();
        while(BusyADC());
        power = ReadADC();
        power16 += power;
}
power = power16 >> 4;
itoa( NS, charbuff);
strcpy(outputB, charbuff);
stringL = strlen(outputB);
outputB[stringL] = 32;
outputB[stringL+1] = 0;
itoa( EW, charbuff);
strcat(outputB, charbuff);
stringL = strlen(outputB);
outputB[stringL] = 32;
outputB[stringL+1] = 0;
voltage = power;
voltage = voltage * 1000;
voltage = voltage / 205;
power = voltage;
asciAcell(power, charbuff);
charbuff[6] = 32;
charbuff[7] = 86;
charbuff[8] = 0;
```

```c
                strcat(outputB, charbuff);
                stringL = strlen(outputB);
                outputB[stringL] = 32;
                outputB[stringL+1] = 0;
                return (outputB);
}

void main (void){

                unsigned char wiznet = 0b10101010, length;
                unsigned int y;
                int pitch, roll;

                // initialize PIC periferals

                OpenUSART(      USART_TX_INT_OFF &    // TX interrupt off
                                USART_RX_INT_OFF &        // RX interrupt off
                                USART_ASYNCH_MODE &        // Asychronos mode
                                USART_EIGHT_BIT&               // 8-Bit
                                USART_CONT_RX &                  // Continous recive
                                USART_BRGH_LOW,          //Low Baud rate formula
                                64);                                   //set approximately 9.6 kbs



                OpenI2C( MASTER, SLEW_ON);      // I2C master mode 100kHz mode
                SSPADD = 99;

                OpenADC(        ADC_FOSC_64 &
                                    ADC_RIGHT_JUST &
                                    ADC_8ANA_0REF,
                                    ADC_CH0 &
                                    ADC_INT_OFF);

                TRISA = 0xFF;
                TRISE = 0x0F;

                OpenTimer0(    TIMER_INT_OFF &
                                    T0_16BIT &
                                    T0_SOURCE_INT &
                                    T0_EDGE_FALL &
                                    T0_PS_1_1 );

                TRISD = 0xFF;
                LATD = 255;

                WriteUSART( 12 );
                // wait for screen to finish clearing
```

```
Delay10KTCYx(50);

while (BusyUSART());
putrsUSART( welcomeMsg);

// wait .5 sec and then clear screen
Delay10KTCYx(250);
Delay10KTCYx(250);
WriteUSART( 12 );
// wait for screen to finish clearing
Delay10KTCYx(50);

status = 0;

// initilase the IINCHIP
status = InitWiznet(wiznet);

// clear buffer
memset(buffer, 0, 80);

// out puts result of initilazation to LCD
// a resut of 1 means the system initilized
while (BusyUSART());
putrsUSART( initStMsg );
while (BusyUSART());
putsUSART(      btoa(status, charbuff) );
while (BusyUSART());
WriteUSART( 10 );

while(1){
        // socket initilazation
        // setting ch0 listen on port 23 for a connection
        status = initSocketCh0( wiznet, 0, 23);

        // clear buffer
        memset(buffer, 0, 10);

        // out puts result of initilazation to LCD
        // a result of 2 means the socket initilizes
        while (BusyUSART());
        putrsUSART( socketInitStMsg );
        while (BusyUSART());
        putsUSART( btoa(status, charbuff));
        while (BusyUSART());
        WriteUSART( 10 );

        // now listen for a connection wait for a connection;
        buffer[0] = 0b00001000;
```

```
i2cTx( wiznet, 0x00, 0x00, buffer, 1);

while (BusyUSART());
putrsUSART( WaitConectMsg);
while (BusyUSART());
WriteUSART( 10 );


// check the Socket State Reister for ch0
// a value of 0x06 means a connection has bee established
while (status != 0x06){
//        Delay10KTCYx(1);

// before connecting display the accellerations for calabration
        getacell(0, charbuff);
        charbuff[8] = 13;
        while (BusyUSART());
        WriteUSART(32);
        stringUARTS(charbuff, 9);
        getacell(1, charbuff);
        charbuff[8] = 13;
        while (BusyUSART());
        WriteUSART(32);
        stringUARTS(charbuff, 9);
        Delay10TCYx(100);
        getacell(2, charbuff);
        charbuff[8] = 13;
        while (BusyUSART());
        WriteUSART(32);
        while (BusyUSART());
        WriteUSART(32);
        stringUARTS(charbuff, 9);
        getacell(3, charbuff);
        charbuff[8] = 13;
        while (BusyUSART());
        WriteUSART(32);
        while (BusyUSART());
        WriteUSART(32);
        stringUARTS(charbuff, 9);
        getanalog((char *) buffer);
        length = strlen((char *)buffer);
        while (BusyUSART());
        WriteUSART(32);
        while (BusyUSART());
        WriteUSART(32);
        stringUARTS((char *)buffer, length);
        i2cRx( 0x08, 0x00, 0xA0, (unsigned char *)&pitch, 2);
        itoa( pitch, (char *)buffer);
```

```
                        length = strlen((char *)buffer);
                        buffer[length] = 13;
                        length ++;
                        buffer[length] = 0;
                        stringUARTS((char *)buffer, length);

                        // wait .2 sec
                        Delay10KTCYx(200);

                        WriteUSART( 12 );

                        // wait for screen to finish clearing
                        Delay10KTCYx(60);

                        i2cRx( wiznet, 0x00, 0xA0, &status, 1);

                }
                while (BusyUSART());
                putrsUSART( conectEstabMsg);

                // wait 1 sec and then clear screen
                Delay10KTCYx(250);
                Delay10KTCYx(250);
                Delay10KTCYx(250);
                Delay10KTCYx(250);
                WriteUSART( 12 );

                // wait for screen to finish clearing
                Delay10KTCYx(50);


                INTCON = 0b10100000;

                // while the connection is open do all this stuff
                while (status == 0x06){
                // check the recive buffer to see if ther is any incomming data
                        //  for the LCD screen and output it
        //              reciveData(wiznet);
                        if(time > 1000) time = 0;
                        timelast = time;

                        // reduces the number of transmissions

                        if ( timelast % 40 == 0){
                                getacell(0, charbuff);
                                charbuff[8] = 32;
                                charbuff[9] = 0;
                                strcpy((char * )buffer, charbuff);
```

```
                getacell(1, charbuff);
                charbuff[8] = 32;
                charbuff[9] = 0;
                strcat((char * )buffer, charbuff);

                getacell(2, charbuff);
                charbuff[8] = 32;
                charbuff[9] = 0;
                strcat((char * )buffer, charbuff);

                getacell(3, charbuff);
                charbuff[8] = 32;
                charbuff[9] = 0;
                strcat((char * )buffer, charbuff);
                length = strlen((char *) buffer);
                trasmitData(wiznet,buffer,length);

                getanalog ((char *)buffer);

                i2cRx( 0x08, 0x00, 0xA0, (unsigned char *)&pitch, 2);
                itoa( pitch, charbuff);
        strcat((char * )buffer, charbuff);
        length = strlen((char *)buffer);
        buffer[length] = 32;
        length++;
        buffer[length] = 0;
        length++;
                itoa( timelast, charbuff);
                strcat((char * )buffer, charbuff);
                length = strlen((char *)buffer);
                if(timelast == 1000){
                        buffer[length] = 32;
                        length ++;
                }
                else{
                        buffer[length] = 10;
                        length ++;
                        buffer[length] = 13;
                        length ++;
                }
                trasmitData(wiznet,buffer,length);
        }

        if( timelast == 1000){  // 275

                // access the GPS and get last update
                i2cRx( 0x0F, 0x00, 0x00, buffer, 80);
```

```
                                           // transmit the last updata
                                           length = strlen((char *)buffer);
                                           trasmitData(wiznet,buffer, length);
                                           time -= 1000;

                                   }
                                   // Check the current conection status
                                   i2cRx( wiznet, 0x00, 0xA0, &status, 1);
                           }
                   }
}
```

Appendix E: Company Contacts

Dr. Stephen Wood: (Professor) (321-674-7244)
        Gave personal insight

Dr. John Sainsbury: (Professor) (321-674-7411)
        Helped with Naval Architect questions

Dyer Matlock: (Masters in education & E.E) (321-725-0783)
        Reviewed the structural design

Eddie Robbins: (Welder) (321-956-9978)
        Helped with materials, assembly design, & manufacturing

John Amero: (School Machinist) (321-674-7228)

        Helped with CNC programming and machine shop training

Bill Battin : (Research Associate) (321-674-7618)

        Assisted with sanding, painting, and waste disposal